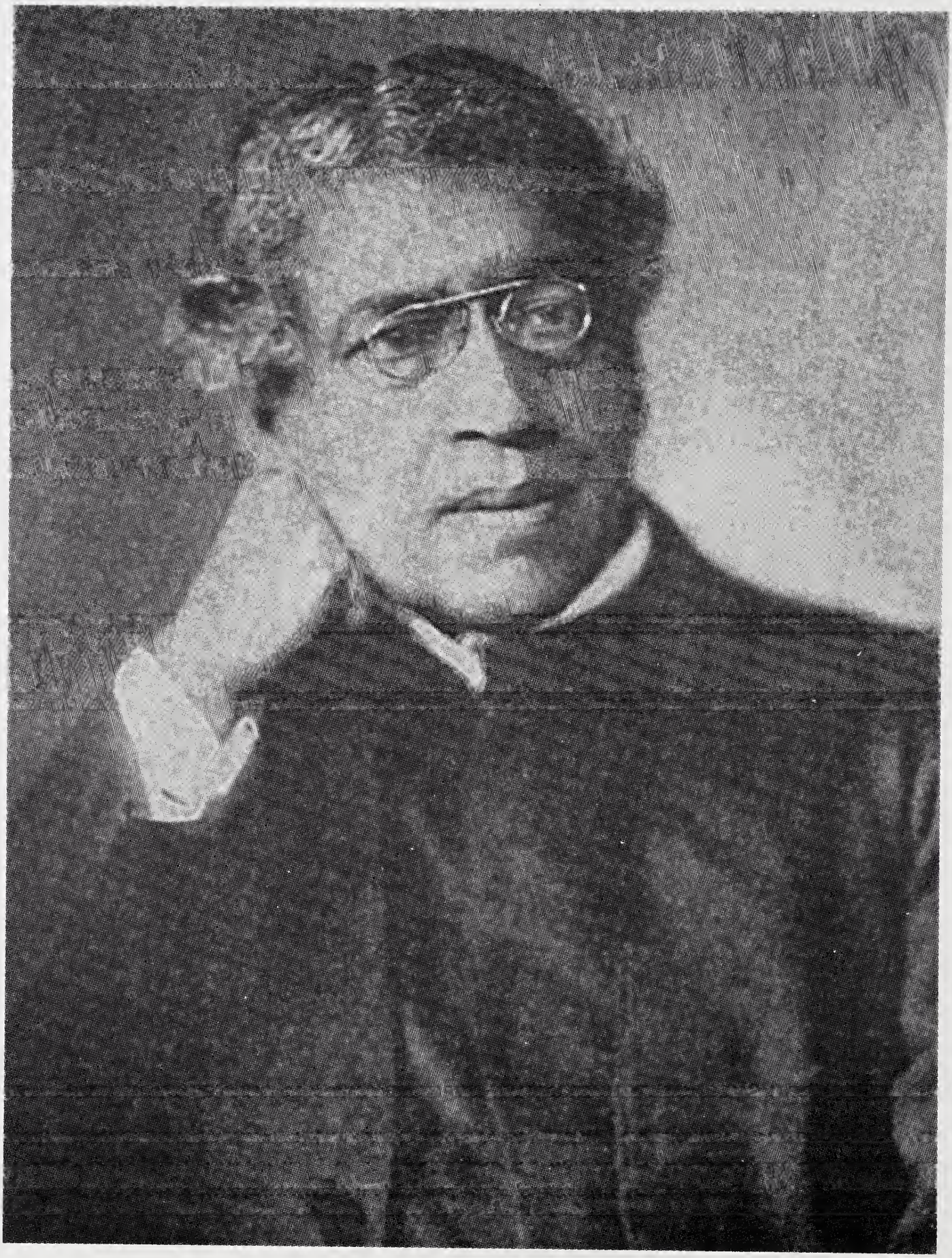
BUILDERS OF MODERN INDIA

Jagadis Chandra Bose

Visvapriya Mukherji

PUBLICATIONS DIVISION



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MINISTRY OF INFORMATION AND BROADCASTING
GOVERNMENT OF INDIA

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ABOUT THE SERIES

The object of the Series is the publication of biographies of those eminent sons and daughters of India who have been mainly instrumental in our national renaissance and the struggle for independence.

It is essential for the present and coming generations to know something about these great men and women. Except in a few cases, no authoritative biographies are available. The Series has been planned to remove this lacuna and comprises handy volumes containing simple and short biographies of our eminent leaders written by competent persons who know their subject well. The books in this Series are not intended either to be comprehensive studies or to replace more elaborate biographies.

PREFACE

If the place of Jagadis Chandra Bose in the world of science is to be described in one sentence, then he should be characterized as one of the pioneers of microwave physics and as one of those who anticipated the science of cybernetics that seeks to unify physics, biology and psychology with respect to the problem of automatic control systems. Indians with excessive patriotism go to the extreme of idolizing Bose as *the* inventor of wireless telegraphy and as a triumphant oriental savant who, through his biophysical researches, has convincingly vindicated the existence of a Supreme Consciousness that unifies all diversities. On the other hand, some critics-rather detractors-go to the other extreme; they underrate his contribution to microwave researches and also consider his bio-physical and plant physiological researches as a metaphysical attempt at fitting empirical results into the Vedic doctrine of unity in diversity. The critics, however, forget that science *does* ultimately aim at consistent unifying principles that establish a comprehensible order in the manifoldness of natural phenomena. It is through a discerning philosophical insight into Nature's diverse manifestations that Norbert Wiener has created the modern science of cybernetics. Both idolization and detraction are, in fact, rooted in ignorance of what Bose actually did. Hence this short biography.

Readers will find in this book a somewhat frequent use of quotations. I have not hesitated to use quotations whenever I have felt that Jagadis Chandra's ideas, ideals and activities can thus be better understood by the readers than through my own expatiating explanations. The letters between Bose and Tagore - especially those from Bose to Tagore - constitute an important source material for learning about Bose firsthand. These letters were written in Bengali - a language they loved and enriched. I have quoted from quite a few of these letters and from a

collection of Bengali essays Bose wrote for popularizing science. Evidently, my translation of them fails to convey the literary flavour which one may expect to find in the original. Nevertheless, their contents would serve the purpose, for which they are used.

This book has no scholarly pretensions. Naturally, therefore, it does not bristle with numbered references for all quotations. Readers interested in knowing more about Bose and his contributions may consult any of the reading materials listed in the bibliography.

Before I conclude this preface, I must express my sincere thanks to Mr. Dibakar Sen of the Bose Institute, Calcutta, but for whom I would not have gained access to the clippings from old newspapers and periodicals preserved in Bose's house. Thanks are also due to the Director and the Librarian of the Bose Institute for all the help extended. I am grateful to Dr. Taraprasanna Ghatak for carefully reading through my manuscripts. With a keen literary sensibility, he suggested many stylistic improvements. Thanks are due to Mr. Krishnapada Sandilya for rendering Tagore's poem on 'Mimosa' (Appendix-IV) excellently into English. I am thankful to my wife Mrs. Sunanda Mukherji for suggesting some improvements in my description of Bose's plant-physiological researches. Thanks are due to Mr. Sadhan Kumar Chakraborty for nicely reproducing some diagrams.

Last but not least, I am thankful to the Publications Division, Ministry of Information and Broadcasting, Government of India, for inviting me to write Bose's biography for this series.

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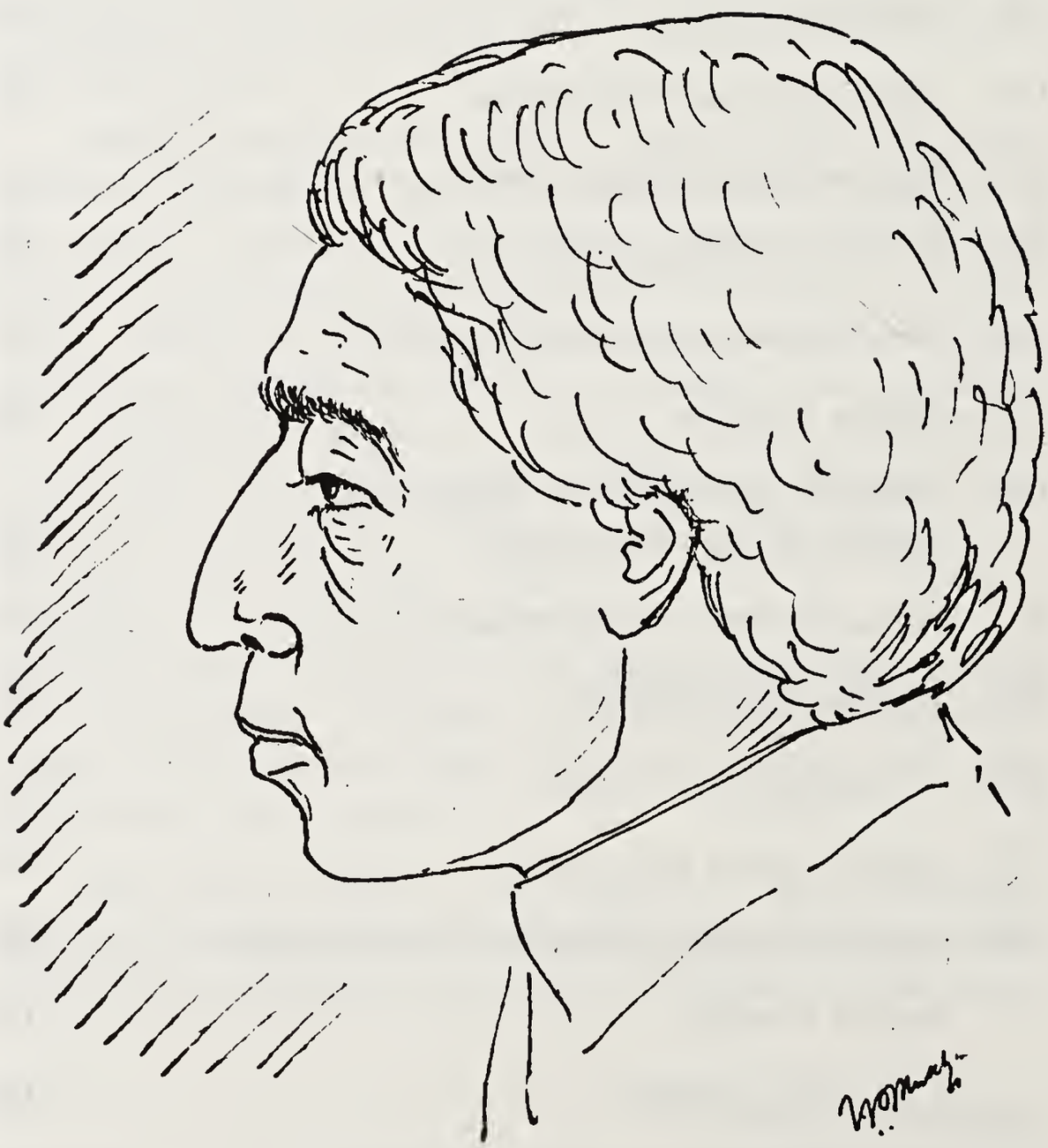

Sketch by the author from a bas-relief plaque of Jagadis Chandra Bose in the Presidency College, Calcutta.

Parentage and Childhood

THAT WAS THE TIME when the battered cannons of the sepoy rebels had just been silenced, and the reign of the East India Company superseded by that of the British Crown. On the first day of November 1858, Lord Canning proclaimed Queen Victoria's intention of establishing a 'Better Government' for Indians. And on the last day of the same month Jagadis Chandra was born in Mymensingh, where his father was posted as a deputy magistrate. The contemporary socio-political climate, in which the Bengali intelligentsia looked up to the Empress of Great Britain as the caressing mother of the Indian people, could have easily made a very loyal government administrator of Jagadis. There was such a possibility especially because he was brought up in the family of a fairly high-ranking government official. But the fact was that he did not choose to go along the beaten track of magistracy or the like, and became a great scientist with a highly sensitive feeling and love for his compatriots. What prompted him to go off the beaten track ? For an answer we have to see what his parents were like and how they brought him up.

Jagadis's father Bhagavan Chandra Bose, whose ancestral home was in Vikrampur near Dacca city, was cast in a special mould. There were two facets of his character. On the one hand, as a deputy magistrate he was a strict disciplinarian and a conscientious dispenser of justice, who would chastise wrongdoers in accordance with the laws of the land. On the other hand, he would season justice with mercy, because as a true patriot and lover of humanity he was aware of the social factors that drove people—especially the underprivileged—to crime. He himself at

times bravely overpowered and arrested dacoits. Some convicted dacoits, after their release from the prison, set fire to his house causing a severe loss of property. Yet he never lost faith in the inherent goodness of man. Once a policeman tried unfairly to throttle his opponent in a wrestling match. The strict administrator took the policeman to task for this violent act and breach of discipline. The revengeful policeman planned later to kill Bhagavan Chandra, but the plan got exposed. The policeman was however awestruck when the powerful government official forgave him and asked him to go back to his duty. Another instance of how Bhagavan Chandra seasoned justice with mercy is worth narrating. Once he caught a notorious dacoit and sentenced him to a long term of imprisonment. Strangely enough, after serving the sentence the ex-outlaw approached Bhagavan Chandra in search of some kind of job for his subsistence. Consistent with his faith in the inherent goodness of man, "my father", writes Jagadis Chandra, "took the unusual course to employ him as my special attendant to carry me, a child of four, on his back to the distant village school. No nurse could be tenderer than this ex-leader of lawless men, whose profession had been to deal out wounds and deaths". The great trust placed upon him by his employer was never abused. Referring to Bhagavan Chandra's attitude towards such socially despised 'criminals', Bose's biographer Patrick Geddes commented :

> "Are criminals often thus kindly and wisely treated ? If not, have not the world's magistratures, nowadays so regularised and formalised in their procedure, something to learn from such old-fashioned predecessors-of whom there have always been a few, but too few in every land?"

Bhagavan Chandra thus salvaged a basically honest and useful member of human society, who would have otherwise slipped back into crime or depravity.

Bhagavan Chandra's sense of social responsibility was however not limited to such acts of kindness to and consideration for individuals only. He believed that economically and culturally sound social institutions would produce better individuals. He therefore took the initiative in organizing melas or annual fairs where local manufactures and agricultural products could be exhibited and marketed. That was one of his attempts to resurrect the ailing rural economy. He also organized jatras or open-air plays and other kinds of performances depicting the folk culture of Bengal.

During his tenure as assistant commissioner of Burdwan malaria broke out in 1870 with great severity taking a heavy toll of the population. Bhagavan Chandra not only organized medical service, but also established technical schools and industries, where orphans might be trained and made self-supporting. A large part of his house and compound was used as a carpentry workshop and foundry, where the foundry-men could cast even a good-sized brass cannon. In 1880, when people were dying of famine, he tried his best to help the starving population. The starvation all around made him so sick that he himself could not eat. His health impaired so much that he had to be on leave for two years.

Even during that period of sick leave he started new ventures such as tea planting in Terai and a textile company in Bombay. The directors of the textile company, on whom he placed great trust, absconded with money. On many other Swadeshi ventures Bhagavan Chandra staked his money and health, and eventually he proved to be a failure. Many decades later (in 1915) Jagadis Chandra, in his presidential address at a conference in Vikrampur, referred to the significance of his father's failures :

> "If you are defeated, if you fail to achieve success, what of it? Let me here narrate the story of a failure. The man, about whom I am going to

speak now, realized half a century back that our country would not make any headway unless our industry, commerce and agriculture were resuscitated. He sacrified much of his life in trying to establish an indigenous textile mill in our country. He met with the same fate that generally befalls all trail-blazers. He incurred great losses in 'his diverse enterprises. He was the first to set up a loan .office at Faridpur for the benefit of peasants. Today it is making a great profit, while he himself suffered privations for its sake. It was he Who initiated the Faridpur mela for promoting agriculture and industry. It was he who established a tea plantation in Assam. There he suffered great losses, but his partners are now reaping rich fruits of his toils. He staked his money on founding technical schools, and ruined himself in directing them. Towards the end of his life he felt that he had floundered and failed in his endeavours. Failed ? True, so far his own life time was concerned, he was a failure; but his failure contributed to the success of many".

Jagadis Chandra spoke again in the same vein at Faridpur on his father's ventures on the occasion of the 50th anniversary of the founding of the mela and exhibition :

"A failure ? Yes, but not ignoble nor altogether futile. And through witnessing this struggle, the son learned to look on success or failure as one, and to realise that some defeat may be greater than victory. To me his life has been one of blessing, and daily thanksgiving. Nevertheless everyone had said that he had wrecked his life, which was meant for greater things. Few realise that out of the skeletons of myriad lives bave been built vast continents. And it is on the wreck of a life like his, and of many such lives, that will be built the greater India yet to be. We do not know why it should be so; but we do know that the Earth-Mother is always calling for sacrifice."

As to educational matters, Bhagavan Chandra had very definite ideas about the role the vernacular schools played in shaping the minds of native children. Jagadis Chandra writes :

"English schools were at that time regarded as the only efficient medium for instruction. While my father's

subordinates sent their children to the English schools intended for gentle folk. I was sent to the vernacular school where my comrades were hardy sons of toilers and of others who... were belonging to the 'depressed classes.' "

Jagadis Chandra remarked at the afore-mentioned Vikrampur Conference (1915) :

"At that time, sending children to English schools was an aristocratic status symbol. In the vernacular school, to which, I was sent, the son of the Muslim attendant of my father sat on my right side, and the son of a fisherman sat on my left. They were my playmates. I listened spell-bound to their stories of birds, animals and aquatic creatures. Perhaps these stories created in 'my mind a keen interest in investigating the workings of Nature. When I returned home from school accompanied by my school-fellows, my mother* welcomed and fed all of us without discrimination. Although she was an old-fashioned orthodox lady, she never considered herself guilty of impiety by treating these 'untouchables' as her' own children. It was because of my childhood friendship with them that I could never feel that there were 'creatures' who might be labelled 'low-caste', I never realized that there existed a `problem' common to the two communities, Hindus and Muslims."

Patrick Geddes comments that "Bhagavan Chandra sent his son to a vernacular school "with outspoken expressions of his two reasons, educational and social—that a child should know his own mother tongue before beginning English; and further, that he should first know his own people, and not be kept apart by that false pride which nowadays in India tends to separate the prosperous classes from their less fortunate brethren."

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*Bamasundari Bose

Such were Jagadis's parents who, through their deeds in everyday life, instilled into their son a deep sympathy and feeling for the underprivileged, the underdog, and the wronged. Jagadis developed an insight into the virtues and inherent qualities of any person, no matter whether he was looked upon as an outlaw, an outcast or a sage by the respectable elite. With this open-minded attitude towards human beings Jagadis estimated the virtues and vices of the epic heroes, with whose roles he became acquainted in his boyhood days through *jatras* and through his serious reading of the *Mahabharata*. Among all the heroes, Jagadis felt deep sympathy for Karna. Many years later (in 1899) Jagadis wanted his friend Rabindranath to immortalize Karna in a poem. In a letter to his, poet-friend, Jagadis gave his appraisal of Karna, in which we find Jagadis's understanding of the wronged and the outcast :

> "Once I requested you to write something on Karna. We are overwhelmed by the godlike character of Bhishma, but we feel sympathy for Karna's unfulfilled life 'which was a combination of virtues and vices. We are attracted towards the man, who could not fulfil himself because of circumstances, in whose life them was always a smouldering conflict between pettiness and magnanimity, who was a human but could have been a god, and whose defeat was nobler than victory."

Rabindranath did compose a dialogic poem *Karna-Kunti Samvad*, in which we find an echo of Jagadis's characterization of Karna. In this connexion let us recall Jagadis's remark that his father's failures had proved nobler than his successes.

Jagadis's later life represented a tribute to all the social and ethical values he had imbibed from his noble parents.

II

Education in Calcutta

BY THE TIME JAGADIS completed nine years he had had a sound grounding in his mother tongue. In 1869 he was admitted to the Hare School of Calcutta and then to St. Xavier's School. St. Xavier's School was chiefly meant for Anglo-Indian and European boys. The champion boxer of his class challenged him on the very first day to fight a battle of fists. Jagadis accepted the challenge and was defeated. But through determination he ultimately proved a victor. This same resolute attitude was to characterize his fights against heavy odds in his future profession as a scientist.

In Calcutta, Jagadis stayed in a hostel, which accommodated boys belonging to different colleges. Patrick Geddes wrote (1920) :

"His pocket money was spent on animal pets, and to their housing and tending his spare time was devoted. In the corner of the compound too he laid out a little garden and spent much ingenuity upon its water-supply, winding about some pipes which he managed to lay hands on, and making a little stream with a little bridge..... It is amusing to note the renewal of this piping and stream in later years in Bose's Darjeeling garden, and Calcutta home, next the Bose Institute. Indeed the writer... cannot but see in this old child-interest the explanation of an otherwise un-intelligibly strong, even emphatic, longing for a stream and bridge in the recent lay-out of his enlarged garden at the Bose Institute last year."

In 1875 Jagadis passed the Entrance Examination and was admitted to St. Xavier's College. There he studied science and

his interest in physics was awakened by the inspiring teacher, Father Lafont.

When Jagadis graduated in 1879 from St. Xavier's College, his father was already a ruined man because of his quixotic ventures. Jagadis felt that he should relieve his father's burden of debts. Jagadis therefore sought his father's approval for his intention to go to England in order to compete for the Indian Civil Service. Although Bhagavan Chandra himself was an able administrator, he vetoed this plan and wished his son to be a scholar, who would "rule nobody but himself". However, Bhagavan Chandra readily consented to his son's intention to study medicine in England. Jagadis left for England.

III

Study in England

IN LONDON, JAGADIS STARTED in 1880 the usual first year study of the medical student. He passed the preliminary examinations in botany and zoology. But when the autumn term began, with anatomy as a new subject for study, Jagadis fell ill with kala-azar, which he had contracted in the forests of Assam during a hunting expedition. The most distinguished physician of the hospital there, Dr. Ringer, treated Jagadis, but failed to cure him. The professor of anatomy and Dr. Ringer advised him to give up the medical course, because the odours of the dissecting room aggravated his illness. Jagadis was thrown into new perplexity, and left London. Through the recommendation of Ananda Mohan Bose* he secured admission to Christ's College, Cambridge in 1881 for studying natural science. There Jagadis was fortunate in having as teachers such leading men of science as Michael Foster for physiology, Francis Balfor for embryology, Sidney Vines for botany, Lord Rayleigh for physics and also others. Rayleigh's inspiring lectures and careful experimentation contributed greatly to the making of a physicist of Jagadis. The role Father Lafont had played in the life of Jagadis at an early stage of his education is comparable with that played by Lord Rayleigh at a later stage.

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*Ananda Mohan Bose (1847-1906), the first Indian Wrangler, founded together with Surendranath Banerjee, the Indian Association in 1876--the forerunner of the Indian National Congress. He presided over the 14th session of the Congress in 1898. He was the first president of the Sadharan Brahmo Samaj founded in 1878. He was closely associated with the Anti-Partition movement in Bengal, and laid in 1905 the foundation stone of the Federation Hall—a symbol of the unity of Bengal. He was J. C. Bose's brother-in-law.

In the course of the following two decades that marked Jagadis's rise as a scientist, Lord Rayleigh and Professor Vines extended to him the kind of help that one might expect only from exceptionally magnanimous, truth-loving intellectuals. In 1884 Jagadis passed the Natural Science Tripos of Cambridge as well as the B.Sc. examination of the University of London.

It should be mentioned that at the time when Jagadis was a student at Cambridge, Prafulla Chandra Ray (Sir P. C. Ray) was a student of chemistry at Edinburgh. They met at London and became intimate friends.

IV

Appointment and Tribulations

BEFORE JAGADIS LEFT FOR home in 1885, Ananda Mohan Bose had procured for him a letter of introduction from Prof. Fawcett, the economist, to Lord Ripon, the then Viceroy of India. Ripon requested Sir Alfred Croft, the Director of Public Instruction, to find Jagadis a suitable appointment. After some initial difficulties Jagadis was appointed officiating professor of physics at the Presidency College, Calcutta at the intervention of the Viceroy. The principal, Mr. C. H. Tawney protested against that appointment but had to accept it as a settled fact.

Prof. J. C. Bose was not given any facilities for research. On top of it he was a victim of racialism with regard to salary. In those days, an Indian professor's salary was two-thirds of what his English counterpairt used to get. Furthermore, on the plea that Bose's post was an officiating one, he was offered only the half of even this two-thirds. Bose's protest was disregarded. With remarkable sense of self-respect and national pride he decided on a new form of protest. He resolved not to accept the salary cheque, and stuck to this decision for three years. Bose married (1887) during that period. The Bose family at that time was in the midst of many privations after the failure of Bhagavan Chandra's Swadeshi ventures. With great fortitude Jagadis Chandra's wife, Abala Bose (nee Das) too faced up to all hardships.

After three years, both the D.P.I. and the Principal realized the value of Bose's work. They could now also see the boldness of his character. Consequently, Bose's appointment was made

permanent in 1888 by a special governmental order, and he was paid off his full pay for the preceding three years. Before receiving this lump sum he had already started clearing his father's debts by disposing of his ancestral home and family property, as also by selling his mother's ornaments. On receiving the arrears of pay he could completely discharge the debts. This earned him the, respect of the creditors, 'who had even offered to write off a part of the debts. Bhagavan Chandra lived one more year and his wife two more years after they got out of debt. Bhagavan Chandra died at the age of 62, when Jagadis Chandra was 32.

Even amid such family tribulations Prof. Bose developed his hobbies such as photography, and started his career as a good teacher of physics and as an indefatigable scientific researcher. Sister Nivedita writes : "I was horrified to find the way in which a great worker could be subjected to continuous annoyance and petty difficulties. .....The college routine was made as arduous as possible for him, so that he could not have the time he needed for investigation." The weekly average of his lecture classes was twenty-six. After this daily grind, which he of course did with great conscientiousness, he carried on his research far into the night in a 20-foot square room in the Presidency College.

At that time there was no laboratory worth the name in that college. It would bear mentioning here that from 1885, i.e. when by coincidence Bose joined the Presidency College, 'Elementary Physics' was added at the University of Calcutta, as a "permanent subject for the F.A. Examination" ('First Arts', which later took the name 'Intermediate'). However, elementary physics was "more or less optional, as students were not required to obtain any minimum number of marks in the subject". From 1891 elementary physics became a compulsory subject, in which a student had to "obtain a small fixed minimum of marks to pass the examination". Only in 1885 practical examinations were

introduced even at the Master's degree level. Moreover, the contemporary science policy* for the colonies was not at all conducive to attempts at original research. Therefore, none under such circumstances, could expect to be favoured with a research laboratory and research grants.

But instead of quarreling with circumstances, Bose confronted them and dominated over them. He spent his hard-earned money for making experimental equipment. He trained up a tin-smith for constructing delicate and reliable pieces of apparatus. Within a decade of his joining the Presidency College, he emerged as a pioneer in the incipient research-field of wireless waves.

*The Royal Society (and also its Indian Advisory Committee, established at the end of the last century) hold the "consistent view that scientists in India should leave pure science to Britain and apply themselves to the applications of science". See Roy M. Macleod, "Scientific Advice for British India : Imperial Perceptions and Administrative Goals, 1898-1923", *Modern Asian Studies*: Vol. 9, No. 3 (1975), pp. 343-384.

V

Researches in Hertzian Waves

FIVE YEARS AFTER BOSE was born the famous British theoretical physicist James Clerk Maxwell mathematically predicted the existence of electromagnetic waves of diverse wave lengths. Maxwell however did not live to see his prediction verified experimentally. He died in 1879.

The British physicist Oliver Lodge concentrated, during 1887-1888, on demonstrating the existence of Maxwell's waves transmitted along wires. He was experimenting on lightning conductors. He failed to demonstrate the propagation of these waves through free space.

In 1888 Heinrich Hertz, a German physicist, experimentally showed the existence of electromagnetic waves in free space, and found their speed to be the same as that of light, as Maxwell had predicted. Hertz further showed that such waves had all the usual optical properties, i.e. the properties of visible light waves. Although propagation along wires and across free space are basically equivalent, Hertz's demonstration of transmission through space was much more spectacular. Lodge pursued Hertz's work and paid a commemorative tribute to Hertz a few months after the latter's death by delivering a lecture in June 1894 at the Royal Institution. Soon Lodge published this lecture in the form of a little book, *The Work of Hertz and some of his Successors*. The widely reported lecture and the widely publicized book of Lodge inspired further work in France, England, Germany, Russia and Italy. For example, in France, Branly (1890) and in Germany, Zehnder (1894) researched into Hertzian waves. In the headquarters of the Czar's Navy at Kronstadt, a

physics instructor, Alexander Popov, constructed a receiver primarily as a detector of approaching thunderstorms, although he was aware (1895) of its usefulness in wireless signalling in association with a suitable transmitter. In 1895, at Cambridge, Ernst Rutherford performed a wireless transmission experiment, but did not pursue that line of investigation further. At the University of Bologna, Augusto Righi incorporated the work of Hertz in his lectures and constructed a transmitter (1894) that was later utilized fully by his pupil Marconi in his commercial ventures. Lodge's lecture caught young Marconi's attention during the summer of 1894.

Lodge's book on Hertz's work caught Bose's eye too. Bose lost no time in seizing upon that line of research. In studying the optical or light-like properties of wireless waves or radio 'microwaves', Hertz had dealt with decimetre-waves (about 66 cm wave-length) and Lodge had dealt with centi-metre-waves (about 8 cm wave-length). The first remarkable aspect of Bose's follow-up microwave researches was that he reduced the waves to the millimetre level (about 5 mm wave-length), i.e. brought them down to within a few octaves of visible light. He knew that long waves were advantageous because of their great penetrative power, but realized their disadvantage for electro-optical investigations, i.e. for studying the light-like properties of those electric waves. He found that the long waves were unwantedly reflected from room surroundings, thereby disturbing all portions of the receiving circuit. Moreover, long waves could not be formed into a well directed narrow pencil of radiation.

The long waves which Hertz had dealt with needed gigantic metallic reflectors, or huge pitch prisms for verifying whether electric waves were reflected or refracted like light. And in order to verify the phenomenon of polarization for electric waves, big wire-gratings had to be used, whereas visible light' waves are polarized through some kinds of natural crystals. Evidently, a big

wire-grating and a crystal do not belong to the same class of substances used as polarizers. Moreover, such a wire-grating is obviously much bigger than a crystal. In starting investigations in the field of Hertzian waves, Bose felt that he must "find natural substances which would polarise the transmitted electric ray", and that "the analogy between electric radiation and light would be rendered more complete if the classes of substance which polarise light were also found to polarise the electric ray. The two phenomena may be regarded identical if the same specimen is found to polarise both the luminous and the electric rays." Bose's experiments with millimetre waves showed that some moderate-sized crystals, which polarise ordinary light rays, "polarise the electric ray just in the same way". And since electric waves can penetrate substances opaque to light, his millimetre waves were also found to be polarized by some types of opaque crystals. He set down this investigation in his first scientific paper, "On polarisation of electric rays by double-refracting crystals", and communicated it to the Asiatic Society of Bengal in May 1895, i.e. less than a year after Lodge had publicized Hertz's work. Bose pursued his investigations, and his second paper, which described a method of determining the index of refraction of sulphur (a substance opaque to light) for electric waves, was communicated to the Royal Society of London for publication by no less a person than Lord Rayleigh in October 1895. In December the well-known London journal, the *Electrician* (Vol. 36, 1895), published Bose's paper, "On a new electro-polariscope", in which he exhibited 'a remarkable virtuosity of devising a short-wave radiator, a sensitive spiral-spring receiver and very efficient polarizers made of jute fibres. At that time the word, 'coherer', coined by Lodge, was used in the English-speaking world for Hettzian-wave receivers or detectors. The *Electrician* readily commented admiringly on -Bose's coherer- (December 1895) The Calcutta newspaper, *The*

Englishman (18 January 1896), quoted from that issue of the *Electrician* thus :

> The *Electrician* thinks that it would be a useful and remunerative work for some practically minded man "to devise a practicable system of electromagnetic light-houses, the receivers on board ship being some electrical equivalent to the human eye. The evolution of a suitable generating apparatus would, we think present little difficulty; that of a suitable receiver, on the other hand seems likely to give considerable trouble. In this connection we would draw attention to the substantial and workmanlike form of 'Coherer' devised by Professor Bose. The sensibility and range of this type of 'Coherer' would appear to leave little to be desired, and it is certainly more likely to withstand the thousand-and-one shocks at sea than any of the forms hitherto brought out." .....Should Professor Bose succeed in perfecting and patenting his 'Coherer', we may in time see the whole system of coast lighting throughout the navigable world revolutionised by the discoveries made by a Bengali scientist working single-handed in our Presidency College Laboratory.
>
> Bose planned to "perfect his coherer" but never thought of "patenting" it.

Bose achieved something very spectacular during the same period. He used his radiator and sensitive coherer in conjunction with a fuse and demonstrated the radio-controlled firing of a cannon. That indeed was a landmark in the history of wireless technology. Bose himself described that event in a popular Bengali essay on the 'Invisible Light'. (*Adrsya Alok*) : "The invisible light can easily pass through brick walls,. buildings, etc. Therefore messages can be transmitted by means of it without the mediation of wires. In 1895 I demonstrated some experiments in the Town Hall of Calcutta. The Lieutenant-

Governor Sir William Mackenzie was present. Electric waves penetrated his colossal body and two closed rooms, and played different kinds of 'havoc' in the third room. The waves fired a cannon, fired a pistol and exploded a gunpowder heap." Thus, by the end of 1895, Bose ranked high among Hertz's successors. Although he planned to send a wireless message from the Presidency College to his residence about a mile away, the plan did not come off, because he left for England in 1896 (see the following chapter).

Bose did not go in for long-distance wireless telegraphy. Since the optical behaviour of radio waves could be best studied with short wave lengths (i.e. very high frequencies), he concentrated on devising millimetre-wave radiators. That was the time, 1895-96, when young Marconi (1874-1937) concentrated on longer wave lengths, because he aimed at a method of signalling over long distances. Distance counted for Marconi. Longer waves meant longer ranges of signalling. He therefore ignored the possibility of designing narrow-beam (i.e. highly directional) wave radiators of short waves, used now a days in radar communication. With his fixation for long waves Marconi indeed achieved in 1901 the technological feat of long-distance radio signalling. However, in the 1920's he became a champion of short-wave radio communication, and in 1935 (i.e. two years before the death of both Marconi and Bose) he experimented on the detection of the motion of troops by the interference resulting from moving bodies in the space between a transmitter and detector.

On the other hand, Bose concentrated on millimetre waves (extremely short waves, i.e. waves of extremely high frequencies), when Marconi dealt with long waves. Bose was not interested in designing any long-distance radio-signalling device and in its commercial exploitation, while Marconi was.

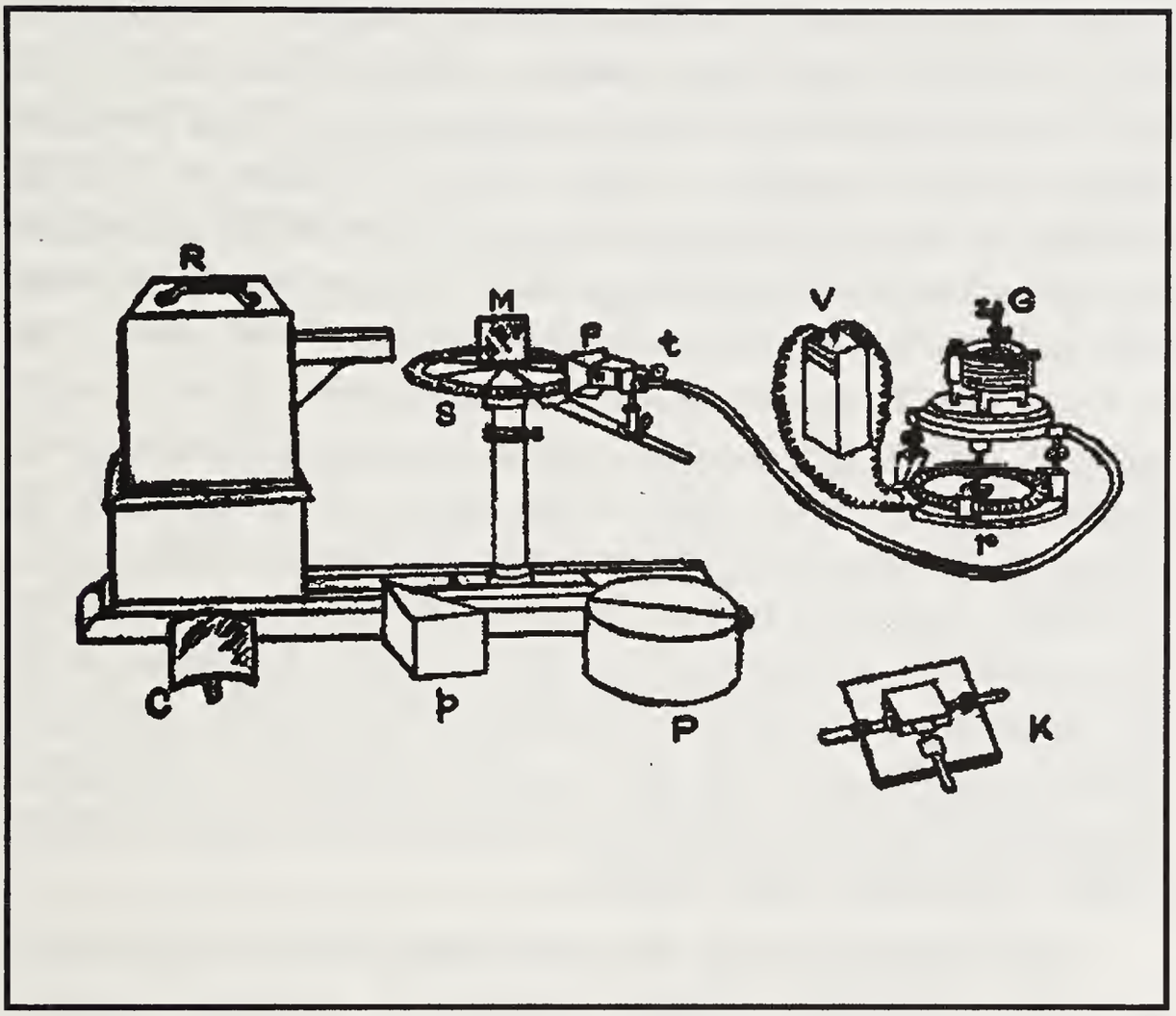

Figure 1

Apparatus for experimenting on Hertzian waves

R, radiator; S, spectrometer-circle; M, plane mirror; C, cylindrical mirror; p, totally reflecting prism; P, semicylinders; K, crystal-holder; F. collecting funnel attached to the spiral spring receiver; t, tangent screw, by which the receiver is rotated; V, voltaic cell; r. circular rheostat; G. galvanometer

Bose's short-wave radiators were quite compact, some of which were about 7 inches in height, 6 inches in length and 4 inches in breadth, some still smaller. He used a cylindrical sulphur lens to render the refracted beam parallel by making the wave-producing spark gap coincide with the focal line of the lens. In this connexion it may be mentioned that Bose refracted electric waves through a pillar of the Presidency College building. As mentioned earlier, Bose was aware of the advantages of short waves for his electro-optical investigations. At the same time he knew that short-wave radiation could not be intense, but he found that "it sometimes becomes necessary to have a greater intensity without the attendant trouble inseparable from too long waves." "I have been able", writes Bose, "to secure this by making a radiator, where the oscillatory discharge [i.e. the wave-producing spark] takes place between two hollow hemispheres and an interposed platinum ball. The intensity of radiation is by this expedient very greatly increased. The parallel pencil of electric radiation is only about one centimetre in diameter." Production of such a narrow pencil of radiation foreshadowed today's directional radar beams.

Just as Bose devised short-wave radiators, he developed a new type of highly sensitive receiver, or 'coherer'. Lodge's metal-filings coherer served well as a receiver. But it needed shaking or tapping for restoring it to sensitiveness almost each time after exposure to electric radiation; moreover, there was a limit to its sensitiveness. Bose therefore devised a new type of coherer, used in series with a cell and a galvanometer. His coherer consisted of some spiral steel springs resting in a cavity scooped out in a block of ebonite. The spirals could be subjected to variable pressure by means of a screw knob to adjust contacts between them. The e.m.f. (voltage) in the spirals could be varied by a potentiometer-slide arrangement. The spirals, exposed to long-continued radiation, lost some sensibility, which could be again maintained fairly uniform by slightly varying the e.m.f.

Bose writes : "The sensitiveness, when necessary, can be exalted to almost any extent, and it is thus possible to carry out some of the most delicate experiments (specially on polarisation) with certainty." We may recall that in 1895 the journal, *Electrician*, spoke highly of this kind of spiral-spring coherer. Bose soon improved upon the coherer by allowing for the humid climate of Bengal. Atmospheric moisture easily oxidized the surface of the springs, thereby diminishing their sensibility. Bose electrolytically deposited cobalt on steel or silver spirals. The contact surface of the coated cobalt was found to be highly sensitive to electric waves, and was not liable to oxidation.

Early pioneers of radio science aimed at designing self-restoring or self-recovering coherers, i.e. detectors which would readily recover their original sensitivity after the cessation of electric radiation. Bose made extensive investigations on various kinds of metals and showed that potassium exhibited a remarkable power of self-recovery. He preferred to call coherers "molecular receivers", because through experimentation he tended to believe that electric radiation causes "re-arrangement of atoms and molecules in a substance" just as light causes "new atomic and molecular aggregation in a photographic plate".

The need of *wave-guides* or radiation-channelling tubes had been felt by the early pioneers of radio-wave researches. Bose used both hollow cylindrical and square wave-guides in his radiators. Likewise he employed a hollow- pyramidal funnel fitted to his spiral-spring receiver. This funnel or horn acted as a radiation-collecting antenna "collecting funnel", as Bose would call it. Such tubes or funnels anticipated the wave-guides of today.

As already mentioned, Bose made an exhaustive study of the polarization of electric waves. He showed great skill as well as imaginativeness by using jute fibres and even locks of human hair and books (interleaved with tin foils) for polarizing and

analyzing the waves. Stretched fibres and hair or book-pages placed parallel to the electric vibrations cut off the rays, while those placed at right angles to the vibrations transmit the rays in a perfectly polarized condition. Moreover, he demonstrated how the phenomenon of *optical activity* (rotation of the plane of polarization), which occurs on passing polarized light through liquids like sugar solutions, can be simulated in the case of radio waves by passing them through twisted struc-tures made of jute fibres. The designing of such simulators bears evidence of Bose's remarkable scientific imagination.

Bose's researches in Hertzian waves culminated in the construction of the "universal radiometer" made of galena crystals. This belongs to a new phase of researches which will be discussed later on.

The following news item from *The Englishman* of 13 December 1895 or *The Statesman* of 14 December 1895 clearly indicates that the Royal Society attached great importance to Bose's work on the determination of the refractive indices of different substances for wireless waves :

> "Father Lafont informs us that Professor J. C. Bose, B.A. and B.Sc. an old pupil of St. Xavier's College and Lecturer on Physics in the Presidency College, had the honour of receiving, by the last mail, a letter from Lord Rayleigh, the discoverer, of argon, regarding a paper `On the Indices of Electric Refraction' communicated by him to the Royal Society. So highly important were these researches regarded that the Royal Society has expressed a desire to make a grant in furtherance, of them from the 'Government Fund for the Encouragement of Original Research' annually voted to the Society by Parliament."

Another line of research that Bose pursued earned him the London University's admiration. That was "the determination of the wavelength of electric radiation by diffraction grating". The

London University's assessment of this work is evident from what Sir Alfred Croft, the then Director of Public Instruction of Bengal wrote to the Secretary to the Government of Bengal in a letter dated 16 June 1896 :

> "The subject dealt with has long been regarded as of very great importance, attempting as it does the complete specification of the unknown forces involved, by determining the length of the invisible wave. .....The problem was attempted by Hertz, and subsequently by many continental physicists but the results obtained were very contradictory. Mr. Bose has recently succeeded in solving the problem with entirely satisfactory results; and a copy of the paper embodying his solution was sent to the University of London as a Thesis for the degree of Doctor of Science. I should explain that, before being admitted to the examination for that degree, a candidate has to produce a Dissertation embodying the results of original research in some branch of science. On the acceptance of the Dissertation by the University, the candidate has in general to undergo a further examination. There is however, a Provison in the D.Sc. Regulations that a candidate may at the discretion of the University be exempted from further examination, provided the paper submitted is of special excellence. Mr. Bose received, on the 27th May, a telegram from the Registrar informing him that his Thesis was accepted and his presence at the examination excused."

This exemption was indeed a great honour. And this thesis, in the form of a paper, was communicated to the Royal Society for publication by Lord Rayleigh and was accepted by the Society within a fortnight. [Published in the *Proceedings of the Royal Society* Vol. 60(1896), page 167].

In this connexion, it should be said that such honours in recognition of Bose's work convinced the Lt. Governor of

Bengal, Sir Alexander Mackenzie, of the need of sanctioning a special annual grant of Rs. 2500 for Bose's own independent researches. Mackenzie was persuaded by Croft to grant another concession to Bose. In the letter quoted above, Croft cited Lord Rayleigh's advice to Bose "that a visit occasionally to Europe would be of great service to your work". Croft wrote :

> "Mr. Bose is now anxious to go to England for six months, in order, in the first place, to attend the meeting of the British Association in September, and if possible, in the second place to visit the chief laboratories of England and the Continent, with the object of gaining knowledge which will be useful for his future work. I beg to submit for the favourable consideration of Government the proposal that instead of taking furlough for this purpose, he should be deputed to visit Europe for six months on the public service. .....In order to justify the proposal, it is necessary for me to submit a brief account of the original work on which Mr. Bose has recently been engaged and of the gratifying recognition which it has received from various scientific authorities in Europe."

Croft describedd the scientific achievements of Bose and also mentioned that the *Electrician* had commented admiringly on his coherer, that the Royal Society desired to finance his researches, that Lord Kelvin had expressed "wonder and admiration" for Bose's work, and that the London University had conferred D.Sc. on him. Croft concluded his letter by urging the Bengal Government to favour Bose with an opportunity to present his scientific paper on Hertzian waves at the British Association meeting in Liverpool and to acquaint himself with the leading European scientists and their laboratories, so that "an efficient laboratory" might be modelled after them in India. In response to this letter (dated 16 June 1896) of Croft, Mackenzie strongly advocated (dated 30 June 1896) "the grant

of the concession (the deputation of Prof. Bose to Europe) asked for". He felt' that "it is the duty of a great Government to do, when it has a man of such exceptional qualifications on its staff', And therefore he attached "much importance to Mr. Bose visiting Europe and conferring with the leaders of scientific inquiry there".

It has been mentioned above that Lord Rayleigh advised Bose to visit Europe occasionally. When Rayleigh came to Calcutta, Bose invited the great physicist to pay a visit to his laboratory. Rayleigh was greatly impressed with what Bose had achieved in that small laboratory and then gave him that advice. Evidently, such an advice from no less a person than Lord Rayleigh was an important factor that prompted Bose to seriously apply for a scientific deputation abroad. And a serious consideration of his application by Croft and Mackenzie facilitated the Governmental sanction of his first scientific mission abroad.

VI

Scientific Missions to Europe

IN A LETTER DATED 7 September 1896 Lord Rayleigh wrote to Bose : "I hope you will pay the promised visit." Rayleigh was eager to see Bose participate in the academic activities of England. With the presentation of a paper on 'Electric Waves' at the Liverpool meeting of the British Association Bose made his debut in England as a scientist. The warm admiration expressed at that meeting by Lord Kelvin for Bose's paper was typical of the response of the scientists present there. Here is a part of the letter Kelvin wrote on Bose (dated 23 October 1896) to Lord George Hamilton, Secretary of State for India, a few days after the Liverpool meeting :

> "He has done exceedingly good experimental work in Calcutta with necessarily very limited means and appliances and has obtained results which are highly valued in England already. .....I have had the pleasure of making personal acquaintance with Prof. Bose at the recent meeting of the British Association in Liverpool, and I have had much conversation with him both there and here, where he has come to see my laboratory..... I believe it will be conducive to the credit of India, and to scientific education in Calcutta, if a well equipped Physical Laboratory is added to the resources of the University of Calcutta, in connection with the Professorship held by Dr. Bose."

British journalists realized that Bose had to do his research in addition to considerable teaching duties and with appliances which in England would be deemed inadequate. Hence Bose's work drew highly appreciative comments from the British Press.

Next, the Managers of the Royal Institution of Great Britain invited Bose to give a Friday Evening Discourse on 29 January 1897. The title of the paper was "Electromagnetic Radiation and

the Polarization of the Electric Ray." Bose started his lecture with these words :

"The work of Hertz in verifying the anticipations of Maxwell has been followed in this country by many important investigations on Electric Waves. The Royal Institution witnessed the repetition of some of the brilliant experiments of Professors Fitzgerald and Lodge. I am glad to have an opportunity to lay before you, at this very, same place, an account of some work which I carried out in India."

In this lecture Bose dealt with his remarkable microwave radiators, spiral-spring coherers and all the associated experimental equipment needed for demonstrating how electric radiation was reflected, refracted and polarized like visible rays. As already discussed in the foregoing chapter, Bose had used books, jute fibres and locks of hair for polarizing electric radiation. The readers may recall that electric vibrations parallel to the pages of a book are absorbed, while those at right angles are transmitted in a perfectly polarized condition. In a popular Bengali essay on the 'Invisible Light' (Adrsya Alok) Bose later described in a humorous vein this polarization experiment done by him at the Royal Institution :

> "The pages of a book are arranged like parallel gratings. When I lectured at the Royal Institution in England, there was on the table a Bradshaw with lists of about ten thousand train-timings and fares printed in small letters. It was so complex that one's efforts to find some information from it would surely fail. I however ignored the enigmatic darkness associated with that book, and experimentally demonstrated that electric radiation could not pass through it when it was held parallel to the vibration; but the book became transparent when it was turned by 90°. Laughter filled the lecture-hall the moment the demonstration was over. This surprised me, but later I understood what had caused so much of merriment. Lord Rayleigh told me, `None was able to see any light through the Bradshaw. You have earned the gratitude of men by showing them how to hold it to see light through it ! My scientific books, which are found abstruse, would certainly become easily intelligible if those are turned by 90^0!'."

Bose concluded the Friday Evening Discourse at the Royal Institution with these words :

> "...The land from which I come did at one time strive to extend human knowledge, but that was many centuries ago; a dark age has since supervened. It is now the privilege of the West to lead in this work. I would fain hope, and I am sure I am echoing your sentiments, that a time may come when the East, too, will take her part in this glorious undertaking; and that at no distant time it shall neither be the West nor the East, but both the East and the West, that will work together, each taking her share in extending the boundaries of knowledge, and bringing out the manifold blessings that follow in its train."

This Friday lecture of Bose convinced the leading British scientists that the Indian mind was as capable of excelling in science as in literature and philosophy, if adequate opportunities were afforded for modern scientific education. Let us recall that Lord Kelvin had already written a personal letter to the Secretary of State urging him to establish a well-equipped physical laboratory at the University of Calcutta under the professorship of Bose. After the Friday Evening Discourse, the Secretary of State received a formal memorandum signed by Lord Lister, President of the Royal Society, Lord Kelvin, Prof. Clifton, Prof. Fitzgerald, Dr. Gladstone, Prof. Poynting, Prof. Silvanus Thomson, Sir William Ramsay, Sir Gabriel Stokes, Sir William Rucker and others. This memorandum convinced the Secretary of State that such a modern laboratory should be set up in Calcutta. He therefore sent the memorandum (May 1897) to the Government of India and expressed his opinion in the covering letter "that the question of establishing an institution of the kind mentioned is deserving of consideration by Your Excellency in Council". However, the well-equipped physical laboratory was founded as late as 1914, i.e., when Bose was about to retire from service.

Bose was to return to Calcutta in April 1897 at the end of his deputation leave. Before leaving the Continent, he lectured on electric waves in March at the Sorbonne University and at the

Societe Fiancaise de Physique (French Physical Society), Paris. Professor A. Cornu, President of the French Academy of Science, chaired the Societe meeting. With the following words he expressed his admiration for Bose's lecture-demonstration : "You should try to revive the great traditions of your race, which bore aloft the torch-light of science and art, and was the leader of civilization two thousand years ago. We in France applaud you and wish you every success." In Germany, Bose's lectures at Berlin, Kiel and other centres of learning produced great impact on the academic as well as journalistic world. In this connexion it may be mentioned that a scientist once approached Prof. E. Warburg of Berlin and said : "The subject of coherer is very obscure and very interesting. I wish to work on it." Warburg interjected "It is undoubtedly very interesting, but it is no longer obscure — there is a man called Bose who has left nothing more to be done." Such was the impact of Bose's microwave research.

On 23 April 1897 Prof. Bose and Mrs. Bose returned from the Continent. They were warmly received at the Howrah station by many intellectuals and admirers such as Ramananda Chatterjee, the editor of the *Modern Review*, Sir P. C. Ray, the well-known chemist, Dr. Nil Ratan Sarkar among others. About a month later a representative of *The Englishman* interviewed Bose and published a report (22 May 1897) :

> "Reminded of what has so often been said about the Indian intellect — that while it is keen, imaginative, subtle, and tenacious it has been said to lack initiative — Professor Bose was further asked whether he thought there was any prospect of a school of original scientists being formed in Bengal or India. He replied that up to the present no opportunities had been afforded for anything of the kind. There were few laboratories, and those were not fitted up with the best or newest appliances. Given these and given

the mental bias produced by a long established scientific curriculum, the Indian mind would prove itself at least as capable of excelling in science as in literature or philosophy."

This clearly expresses Bose's faith in our country's potentialities for great scientific achievements.

After his return Bose pursued research into self-cohering receivers, and tended to believe that electric waves modified the molecular structure of matter. He hypothesized that some kind of allotropic modifications took place in some substances such as silver, when it was exposed to electric waves. And the so-called allotrope or the "radiation product" of silver, he supposed, caused a "fatigue" or loss of sensitiveness of the coherer.

We may consider his efforts in this direction to be of special significance, because it was through these efforts, that he hoped to arrive at "the borderland between physics and chemistry" and devised the first semiconductor receiver, the galena detector, in course of his search for a self-recovering coherer sensitive to microwaves as well as visible radiation. Moreover, it was through his study of the "fatigue" of the coherer that his interest shifted, so to say, logically towards the borderland of physics and biology.

Bose approached the borderland of the living and non-living. He believed molecular changes and strain to be the ultimate cause behind the phenomena of fatigue and recovery in animal muscles as well as coherers. In working with receivers for electric waves, he found that under continuous stimulation by the microwave radiation, the sensitiveness of the metallic detector disappeared. But after a sufficient period of rest it regained once more its normal sensitiveness. He found that they were very similar to those exhibiting fatigue in the animal muscle. And just as animal tissue, after a period of rest, recovers its activity, so did the inorganic receiver recover after an interval of rest. Thinking that prolonged rest would make the receiver

even more sensitive, he laid it aside for several days and was astonished to find that it had become inert. A strong electric shock now stirred it up into readiness for response. Two opposite treatments were thus indicated for fatigue from overwork, and for inertness from long passivity. According to Bose, a muscle-curve registers the history of the fundamental molecular change produced by excitation in a living tissue, exactly as the curve of molecular reaction registers an analogous change in an inorganic substance. The two represent the same thing; in the latter the molecular upset is evidenced by the change of electric conductivity, while in the former it is manifested by the change of form.

Bose felt that he was about to achieve a unification of the realms of the living and the non-living. And therefore he became eager to put forward his experimental results and inferences before Western scientists, many of whom were to meet at the International Congress of Physics associated with the Paris Exhibition in August 1900. Bose therefore met the Lt.-Governor, Sir John Woodburn, in 1900 and expressed his intention to be deputed to that Congress. The Director of Public Instruction was informed of Bose's desire. The D.P.I. failed to appreciate the importance of Bose's new scientific research and remarked : "The only difficulty is that there is no one who can take up your work during your absence, the college will suffer." However, since the Lt.-Governor favoured Bose's supplication for deputation, the Secretary of State sent his approval towards the end of June 1900. Bose started for Paris in mid-July 1900 aboard 'S.S. Arabia'.

At the Congress in Paris, Bose presented his paper "On the general molecular phenomena produced by electricity in living and non-living matter". There he discussed the response (increase of electric conductivity represented by increased deflection of the galvanometer coil) of "magnetic oxide of iron, Fe_3O_4, to the

action of stimulus of electric radiation. .....Under the stimulus of electric waves the induced molecular change causes an increase of conductivity represented by" a larger deflection of the galvanometer. "On the cessation of the stimulus there is a recovery, the galvanometer deflection returning" from the large value to the original value. According to Bose, the invisible *molecular change* was thus revealed by the visible deflection of the galvanometer coil. The effect of an "instantaneous stimulus on the inorganic receiver" is that there is a latent period, the response taking place a short time after the incidence of the stimulus; the response continues for a short period even after the cessation of stimulation; it attains a maximum after which the substance begins to recover, at first quickly, then more slowly. In all this, an analogy is found with the response curve of muscles, in which also there is a short phase of latent period, a phase of increasing action and a phase of recovery. The response of many inorganic receivers was found to exhibit the peculiarity that while moderate intensity of stimulus produced the normal response, a feeble stimulus elicited the opposite reaction. He succeeded in demonstrating the occurrence of similar reactions in living tissues, as for example in the physiological action of drugs, which might be regarded as chemical stimuli. A small `dose' in such cases is often found to give rise to an effect precisely opposite to that produced by a large dose.

Bose, in his paper, also referred to the effect of some chemical substances on the inorganic receivers; some of the substances acted as stimuli that raised the sensibility of the receiver, and some acted as depressants that "abolish the sensibility like `poisons'." In conclusion, Bose affirmed his faith in the ultimate oneness of physical and biological phenomena:

> "In all the phenomena described above there is no break of continuity. It is difficult to draw a line and say 'here the physical phenomenon ends and physiological begins' or 'that is a phenomenon of dead matter and this a vital

phenomenon peculiar to the living'; such lines of demarcation do not exist."

From a letter of Bose to his friend, Rabindranath Tagore (dated 31 August 1900, London) it is evident that after the Congress, Bose expressed to the Congress Secretary his intention of unifying physics, physiology and the psychology of memory into a grand synthesis; Bose writes in that letter :

"The Congress Secretary commented that my theory was novel in all respects and at least two years would be needed to propagate this theory. He advised Don't preach it at one sweep — people won't be able to digest so much surprise, it is human nature.' .....He further said : 'Physicists don't know physiology and vice versa. On top of it, if you bring in psychology, they would understand nothing. Moreover, psychology, memory, etc. are beyond physical science. If you introduce these, they would consider you dreamy. Therefore, you had better start with expressing., purely physical aspects.' ...."

Bose now proceeded to England to put forward his views there. His lecture "On the Similarity of Effect of Electrical Stimulus on Inorganic and Living Substances" at the British Association meeting in Bradford (September 1900) had a great impact on some leading British scientists. Prof. Oliver Lodge, who was looked up to as an authority on coherers, came to that meeting to contradict Bose's theory of molecular strain. (Already in February 1900, Bose had published in the *Proceedings of the Royal Society* a paper "On Electric Touch and the Molecular Changes Produced [Induced], in Matter, by Electric Waves", in which he claimed to have established that Lodge's theory of the conductivity-variations of coherers was inadequate, and that only the theory of molecular changes due to electric radiation could explain all types of conductivity-variations). However, after the question hour, Lodge accepted Bose's view and said to

Mrs. Bose : "Let me heartily congratulate you on your husband's splendid work."

Leading scientists like Lodge and Rayleigh saw in Bose's work a philosophy of science typical of the synthetic oriental mind. But they cautioned him, like, the Paris Congress Secretary, against making premature attempts at a synthesis based on inspiration. Lodge wrote to Bose : "Many congratulations on your very important and suggestive experiments but go slowly, establish point by point and restrain inspiration." Rayleigh remarked : "Going too fast! Proceed slowly." Such notes of caution seemed to Bose to be a reflection on the oriental mind, which according to Western critics would aim at a comprehensive philosophical synthesis without passing through the rigour of an adequately analytical scientific procedure. But it was those very notes of caution that prodded Bose to substantiate his generalizations with greater precision and meticulousness.

Whatever might be their reservations about those generalizations, Prof. Lodge, Prof. Barret and others found in Bose an extraordinary man in the field of science, and they offered him a professorship at a well-known British university. Bose however was in two minds about the offer. On the one hand, he felt that he would need about two more years to pursue the new line of research and for that purpose he needed a good laboratory and a truly academic climate, which the routine grind of the Presidency College could not offer. On the other hand, his sense of social responsibility to his motherland prompted him not to be tempted by offers of attractive posts abroad. Anyhow, Bose was anxious to complete the work he had started. This anxiety was expressed by him in a letter (dated 2 November 1900) to Tagore :

".....Yesterday I received a letter from Sir William Crookes. He writes : 'I have read the most interesting account of your researches with extreme interest. I wonder whether I could

induce you to deliver a lecture on these or kindred subjects of research before the Royal Institution. If you could do so, I shall be very glad to put your name down for a Friday Evening Discourse after Easter of 1901. I have a vivid recollection of the great pleasure you gave us all on the occasion when you lectured a few years ago [i.e. in 1897] .....' — Unfortunately, my deputation period will expire before Easter. I don't feel like asking for further leave; moreover, I doubt whether leave would be granted even if I ask for it. Meanwhile, I met the great physiologist, Dr. Waller. I have been invited to deliver a lecture at the leading physiological society here. Initially, Dr. Waller had been highly critical of me. Later he understood me somewhat and said excitedly : 'It appears that your work will probably upset mine. Truth is truth, and I don't care a d—, if I am proved to be wrong. So come and work; I will place my laboratory at your disposal. Teach me or let us work together.' — I cannot explain to you how much work remains to be done. It will take a considerable time to construct the experimental equipment. Only now I have just started getting some opportunities for beginning my work. If I could stay here for two more years, I would have completed the work. I won't get any physiological laboratory, etc. in my own country. I cannot decide what I should do. If the work is interrupted now, much time would be wasted on starting the work afresh a few years later. Moreover, at the present moment people feel interested in these problems; therefore, this is the opportune time for doing it. I feel that I should go back home, and arrange for leave so that I may be here for two more years. I can do a great deal of work, if I don't have to depend on others' favours...".

Bose did not accept any university post in England, but applied for leave, because all his well-wishers advised him not to go back home before completing the research. He applied for a one-year leave, but only a six-month leave was granted. And during that short period, about a month flowed by fruitlessly,

because he was prescribed a four-week rest by the doctor after a surgical operation in mid-December 1900.

Bose could have at that moment easily rid himself of all worries about leave and associated financial problems, if he had accepted the proposal of collaboration made by Messrs Muirhead & Co. in connection with the commercial exploitation of wireless telegraphy. But he felt a revulsion against such a money-making pursuit; he needed time for pursuing his new line of research in the borderland of physics and physiology. In a letter dated 3 January 1901 Bose writes to Tagore :

> "Perhaps I wrote to you earlier that the well-known electrical company `Messrs Muirhead & Co.' had achieved remarkable results in wireless telegraphy by adopting my suggestions. They said further that they had been groping in the dark and had experienced disappointments through many fruitless endeavours, but they now made great advances by using my theory. I have written another new paper which, I hope, would benefit practical wireless telegraphy in many ways. Dr. Muirhead requests me to keep my new discoveries secret. But my time is short, much remains to be done. If I am once enticed into minting money, I will fail to do anything else. I cannot explain to you what a novel domain I have trodden on, what an amazing theory I am catching a glimpse of .....I have to devote myself to the pursuit of that truth."

Here Bose describes the "enviable laboratory" of Dr. Waller who offered him the opportunity for working there.

Bose was anxious to go abroad every few years for pursuing and publicizing his new line "of research, but he was averse to the idea of setting there in pursuit of money. In a letter to Tagore, Bose expressed a desire to stay abroad even for five years, so that he could disseminate his ideas in countries like Germany, France and U.S.A. too.

In the midst of such anxieties and enticements, the day of the post-Easter Discourse at the Royal Institution drew near, for which 10 May 1901 was fixed. In a letter dated 3 May 1901 to Tagore, Bose writes :

".....Only a week is left before my ordeal; on that occasion I will face the test of whether I can raise your banner [of the East] in the Western world .....Physiologists refuse to believe that physiology belongs to physics. I don't claim that I can establish this point in one day. The men of science and Christians of this country take it for granted that life is a sublime entity placed at a much higher plane above the world of the non-living ...Some physiologists told me, 'You have worked with metallic particles. If you can pinch a solid metal and show some signs of its sensitive response, there won't be any doubt about your contention.' — I have constructed a new apparatus, which automatically records the response caused by 'pinching'. There is no distinction between his response record and that caused by pinching our body (which physiologists have got). My apparatus records the throb of inorganic matter, just as the pulse indicates the throb of life."

It should be mentioned here that in connexion with his research in the borderland of physics and biology, Bose had already devised, more than a year earlier, a sensitive detector of a wide range of electromagnetic waves — a simulator of the eye, or an "artificial retina" (see Chapter VIII). Although Bose was quite aware of the worth of this device as a unique wireless detector, he was chiefly interested in its use in his new borderland research. But Messrs Muirhead & Co., for example, saw in this device a great possibility for perfecting wireless telegraphy and therefore considered it to be a lucrative investment. It was because of this realization that just a few hours before the Royal Institution Discourse, the "millionaire proprietor [perhaps none else than Dr. Muirhead] of a well-known telegraph

company" sent Bose a telegram wishing to meet him urgently. Bose writes :

> "I communicated to him that I had no time. But a reply came, `I myself am coming to you'. Shortly he popped in with a patent form in his hand. He requested me, `Don't disclose all the details in your Discourse. There is money in it. Let me take out a patent for you. You do not know what money you are throwing away! Of course, I will only take half share in the profit — I will finance it'. This millionaire came to me like a beggar in order to make more money! ...I declined his offer."

A true academician as he was, Bose conquered all temptations, and got ready foil delivering the Discourse. The 10th of May arrived. Bose, was to speak on "The Response of Inorganic Matter to Mechanical and Electrical Stimulus". Here is a description of the meeting based on a letter written to Tagore by a scholarly British lady, who witnessed it :

> "At nine o'clock in the evening the chairman led Prof. and Mrs. Bose into the lecture hall They were followed by a train of eminent savants. Bose looked round and started his Discourse in a relaxed and composed manner. At his back hung big diagrams showing response records of muscles under the action of poisons and heat and in fatigued states as well as analogous records of metallic substances. The experimental equipment lay on the table before him.
>
> "You know quite well that Bose is no orator. He doesn't find it easy to make speeches. ...His manner of speaking is characterized by emotions and diffidence. But that evening all his diffidence disappeared! I had never heard him speak with such ease. At times his gait assumed a remarkable gravity and beauty. ...He demolished easily, so to say, the walls that divided chemistry, physics and other disciplines from one another. Then, the scientific definitions that characterized the distinctions

between the living and the non-living were brushed aside by him, as though those were cobweb. ...Prof. Bose became ready to show us the death pang of a piece of metal, which was `dying' under the action of poisons and was about to `revive' under the action of antidotes.

"At last, when the professor demonstrated his new device, the so-called `artificial eye' — an apparatus with a much greater power than the human eye, the audience was filled with boundless amazement.

"I fail to express what a thrill I felt, when the traditional Indian message of a grand cosmic unity was restated today in the language of modem times. ...His individual self seemed to disappear, and his nation emerged before our eyes. ...We realized that at long last India established the excellence of her wisdom before an assembly of Western scientists, and emerged as the preceptor and not as a disciple, nor even as an equal."

In the Friday Evening Discourse, Bose demonstrated the "universal applicability of the test of electric response". He said that the intensity of electrical response is a measure of physiological activity. When this physiological activity of the living substance is diminished by anaesthetics, the electrical responses also become correspondingly diminished. And when the living tissue is in any way killed, the electrical response disappears altogether. Hence Waller said `that the most general and the most delicate sign of life is electrical response'.

Thus, electrical response is regarded as the criterion between the living and non-living. Where it is, life is said to be; where it is not found, we are in presence of death, or else of that which has never lived : for in this respect there is a great gulf fixed between the organic or living and the inorganic or non-living. The phenomena of the inorganic are dominated merely by physical forces, while on the other side of the chasm, in the domain of the living, inscrutable vital phenomena, of which

electrical response is the sign-manual, suddenly come into action. Bose then asked :

"But is it true that the inorganic are irresponsive?...

Are their particles forever locked in the rigid grasp of immobility? As regards response, is the chasm between the living and inorganic really impassable?"

He then demonstrated the "electric reponse" of a piece of tin wire by subjecting it to some "mechanical stimulus" such as "torsional vibration". He showed :

> ".....how similar the response curves of the inorganic are to those of the living substance. We have yet to see whether the similarity extends to this point only, or goes still further. Are the response-curves of the inorganic modified by the influence of external agencies, as the living responses were found to be ? ..... I shall now place two sets of curves side by side, when it will become apparent whether or no similar external influences produce similar results in the two classes of phenomena".

Bose showed that rapidly succeeding stimuli produced analogous response curves in living tissues and in metals. The "fatigue curve .....obtained from tin that had been acted on for several days" exhibited "its remarkable similarity to the curve of fatigue in muscles".

He then demonstrated his device, the "artificial retina", which exhibited very striking response to electromagnetic radiations ranging from ultraviolet to Hertzian waves. Its response curves were shown to closely resemble those of a frog's retina recorded earlier by Waller. Bose mentioned that this "artificial retina" or universal radiometer could also be used as a highly sensitive and efficient wireless detector. In fact, it was because of this prospect that the wireless tycoon Muirhead had an eye to its commercial exploitation. And it was perhaps

because of this that Bose, in describing his device, did not mention there the important fact that the "retina" was made of galena — a lead-salt photoconductor. Many wireless tycoons were present in that lecture, and somehow the notebook that Bose had kept on the demonstration-table for his assistant. disappeared after the lecture.

Anyway, since Bose, in his Discourse, was chiefly concerned with demonstrating the response-analogy between the living and non-living, he very casually suggested the role his "artificial retina" could play in wireless telegraphy, and proceeded to the description of "effects of chemical reagents" on the living and non-living. He showed how a reagent like sodium carbonate or caustic potash administered in "toxic doses" produced a "killing action" on tin, that is, its "normal electrical pulsation" ceased, just as a living tissue is killed by poisons and ceases to exhibit electric reponse. "But we may, sometimes at least, by the timely application of a suitable antidote, revive the dying response, as I do now, by an appropriate injection. See how the lethargy of immobility passes away; the pulse-throb grows stronger and stronger, and the response in our piece of metal becomes normal once more." Bose also demonstrated in analogy with what is experienced in "medical practice", that "the same reagent which becomes a poison in large quantities may act as a stimulant when applied in small doses".

After showing that evening (10 May 1901) the remarkably similar "autographic records of the history of stress and strain in the living and non-living", Bose concluded thus :

> "Among such phenomena, how can we draw line of demarcation, and say, 'here the physical process ends, and there the physiological begins'? No such barrier exists.
>
> "Do not the two sets of records tell us of some property of matter common and persistent ? Do they not show us that the responsive processes, seen in life, have been foreshadowed

in non-life ? — that the physiological is, after all, but an expression of the physical? — that there is no abrupt break, but one uniform and continuous march of law ?...

"It was when I came upon the mute witness of these self made records, and perceived in them one phase of a pervading unity that bears within it all things — the mote that quivers in ripples of light, the teeming life upon our earth, and the radiant suns that shine above us — it was then that I understood for the first time a little of that message proclaimed by my ancestors on the banks of the Ganges thirty centuries ago —

'They who see but one, in all the changing manifoldness of this universe, unto them belongs Eternal Truth — unto none else, unto none else !' "

Among the audience there were such great savants as Prince Kropotkin, Sir William Crookes and most of the leading British men of science. Some of them walked up to Bose and congratulated him on his splendid work. Crookes was so overwhelmed by the Upanishadic quotation uttered by Bose at the end of the Discourse that he requested Bose, 'Please don't forget to include the concluding quotation when the Royal Institution publishes your Discourse. I have scarcely heard anything so grand.'* Sir Robert Austen, an authority on metals, blurted out, 'I have all my life studied the properties of metals, I am happy to think that they have life !' This, of course, was an emotional rhetoric, but Austen later told Bose seriously that he himself had once hesitantly raised the question of a possible similarity between the living and non-living at a Royal Institution Discourse, but he had been bitterly criticized. Austen

*The last paragraph of this lecture (along with the 'grand quotation') occurs in *Royal Institution Library of Science (Physical Sciences)* Vol. 5, pp. 417-440 (Elsevier 1970). But Bose excluded this from his *Collected Physical Papers.*

complimented Bose on convincingly proving and propagating his views with remarkable boldness.

Bose's lecture indeed prompted a few scientists to appreciate his efforts that aimed at unifying organic and inorganic phenomena in terms of some ultimate physico-chemical causes. But Bose's approach was also misinterpreted as an emotional figment by some journalists, who thrived chiefly on disseminating non-scientific, banal and sensational news. On the other hand, even some men of science, who admired Bose, failed unfortunately to look deep into his scientific approach, and superficially understood his work as something metaphysical and something to do with the world of the spirit ! Bose later rightly felt that the philosophical quotation he had uttered at the end of the Discourse created such impressions. A magazine, *The Globe*, commented sarcastically on the Discourse in connexion with his experiments concerning metallic response to mechanical or electric shocks :

> "The Professor's eyes were full of tears. This does him credit; but it will be long before he induces the British householder to pet the fire-iron when it falls on the fender because the fall hurts the fire-iron."

On the other hand, "a well-known electrician, Mr. Swinton", writes Bose, "told his friends after my Discourse, 'This is something beyond science, this is esoteric Buddhism ! ....." Bose felt that more time would be needed to propagate the scientific essence of his views.

After the Royal Institution Discourse, Bose was invited by the Royal Society to present his paper on inorganic response on 6 June 1901 before the leading experts in physiology. Sir Michael Foster, the Secretary of the Royal Society, took the initiative. Bose rightly sensed that he would have to face many obstacles. He wrote to Tagore a week after the Discourse (i.e. on 17 May 1901) :

"Physiologists consider life to be something very lofty. They are not at all ready to admit that their science is mere physics. .....Some foolish people think that if life process is explained scientifically, there won't be any necessity of believing in God. They feel elated. Consequently some devout Christian scientists are filled with dismay. I am therefore going to be deprived of the sympathy and co-operation of some famous scientists. Dr. Waller, who claimed to have discovered the fundamental nature of life, feels hurt. Therefore, I have to fight so many opponents single-handed. I am not sure what the future has in store for me. Disinterested men of science are quite excited about my work.

Before Bose delivered his lecture at the Royal Society on 6 June, his Royal Institution Discourse had already been accepted by the Royal Society as a special case (they never generally accepted anything read before another society) but was yet to be published in its Proceedings. In describing the Royal Society lecture, Bose wrote to Tagore :

"You have heard the name of a leading European physiologist, Burdon Sanderson. For a long time Sanderson, and Waller reigned supreme in the field of physiology..... When I lectured at the Royal Society, I showed that if the responsiveness of inorganic matter and that of animals have ultimately the same basis, the intermediate being — the plant — too has an analogous response [i.e. electric response]. Burdon Sanderson interjected : 'I have carried on a life-long research in botany; only *Mimosa* [a well-known sensitive plant] responds, but that ordinary plants should give electrical response is simply impossible; *it cannot be.'* He said further : 'Prof. Bose has applied physiological terms in describing his physical effects on metals. Though his paper is printed, yet we hope he will

> revise it and use physical terms and not use our physiological expressions in describing phenomena of dead matter.' I retorted that none had a monopoly of scientific terms; moreover, these phenomena are identical, and I am against preaching [the doctrine of] manifoldness, disregarding [the reality of an ultimate] unity."

Bose felt that he intruded into the domain of physiology and thereby offended the etiquette of another form of "caste system". He satirized this caste system in a letter to Tagore :

> "In this country [England], professional men belonging to different disciplines are at great variance with one another. ...Physicists and chemists with one another ! And physiologists with both ! 'Beware, none should overstep the respective boundaries ! We are physiologists, we determine the nature of living things—we do not deal with dead matter. We do not depend on mere physical laws.'....."

Bose estimated that in order to substantiate his hypothesis through further experimentation he needed at least two more years of leave, if not five more years. But by September 1901 his deputation leave was to expire, after which he was supposed to return home. And evidently, once back home, he was likely to be deprived of the annual scholarship and research grant of Rs. 4,500, which he received from the Government. Moreover, very little time and laboratory facilities would be available for private research in Calcutta. He therefore applied for a two-year extension of his leave but the Secretary of State did not grant it. Then Bose applied (July 1901) for furlough. It was granted, but his salary was slashed so much that he was greatly dismayed. Nevertheless, he did not lose heart, because "he knew that there were friends and well-wishers at home and abroad who realized the worth of his new line of investigation and would therefore come to his aid, morally and materially.

Sir William Crookes told Bose : "You will learn that many are engaged in this country [England] in research work. .....which will lead to nothing, but you have got something, of which there will be no end." Another veteran British scientist, who was witness to many epoch-making discoveries and scientific advances for half a century, told Bose : "You will very probably not live to see it universally accepted, it is too daring for this theological country. If you could persist, the younger generations would have accepted you. You ought to go to Germany. But can you stand by yourself for years ? Those who succeeded had, brilliant disciples, they devoted themselves to the master. Have you any ? You think scientific men are liberal — they are the most conservative of peoples. They are contented with what they have now. Doubt is the Devil. Your theory upsets the old established physiological dogmas. Do you think they will easily give up, unless you make them ? Have you made up your mind to fight single-handed for years ? Then and then only they will come round. But if you leave it now, they will try not to think of it, and the thing will be forgotten, till some one else takes it up and makes a name by it". Bose did not have any disciples, but "I have", writes Bose, "confidence in my own persistence".

Such encouragements from some disinterested British savants boosted his morale. Moreover, they were ready to offer him good laboratory facilities for experimental work, provided the finance needed for it was forthcoming.

Bose's predicament in respect of finance became evident to his friends and some public-spirited intellectuals in India. Romesh Chandra Dutt, a well-known historian and a distinguished member of the I.C.S., understood Bose's problems very clearly, because at that time he too was in London. He advised Bose not to return to India before completing his research. R. C. Dutt wrote a letter on 16 July 1901 (see APPENDIX-I) to Tagore appealing to him to raise, through his "immense influence in the

country", the amount of money needed for making Bose free from all financial worries. Already Tagore had been trying to do so. He now went to Agartala to meet his friend, the Maharaja of Tripura — an affluent native prince — to persuade him to gift away at least Rs. 15,000, which Romesh Dutt had estimated to be "absolutely necessary" for Bose. At the poet's instance the Maharaja did unstintingly gift away Rupees 15,000 to Bose.

This financial aid greatly heartened Bose up, and with the furlough having been granted, he could extend his stay in England for two more years. But his controversy with Sanderson at the Royal Society meeting of 6 June 1901 gave rise to a new situation. The consequence of the controversy was that his papers ceased to be published by the Royal Society. A conspiracy of silence was initiated by some physiologists, because if his theory proved true, their theory would be demolished. They thought : since Bose was about to return home, they would be safe, once he crossed the sea.

At that time Tagore's encouragement and help prompted Bose to decide on a longer stay there. But Bose lost all hope of publishing the results of his experiments, because people would ask, 'Whom are we to believe — physiologists who have grown grey in working out their special subjects — or a young physicist who comes all of a sudden to upset all our convictions ?

Meanwhile, Bose chanced to meet Prof. Vines, the President of the Linnean Society, who was the doyen of the modern vegetable physiologists. And the Linnean Society was the leading society in the field of biology. One day Prof. Howes (successor of T. H. Huxley at the Royal College of Science) and Prof. Vines came to see Bose's experiments at the Royal Institution laboratory, where he could continue his research. They were delighted in these experiments. Prof. Howes said repeatedly; 'I wish Huxley had been living now, he would have found the dream of his life fulfilled.'

Then, Vines invited Bose to deliver a lecture at the Linnean Society. Howes was its Secretary and Vines its President. Bose was engaged in a lone battle against his opponents — a group of physiologists and biologists. Within 15 minutes he felt that he triumphed. He heard many applauses such as Bravo! Bravo! After the lecture was over, the President asked three times whether anybody would dispute it. There was total silence. Thereafter Prof. Hartog remarked, 'We have nothing but admiration for this wonderful piece of work.' The President too spoke words of praise. Bose writes to Tagore from London (dated 21 March 1902) :

> "At long last, therefore, I have triumphed for the first time in my struggle. However, much is yet to be done. ...Please inform the Maharaja of Tripura of all this. Without your generous initiative that made my stay here possible, I would have returned home a failure...
>
> Yours Jagadis"

Bose's joy of triumph got a jolt when early in May 1902 he came to know that Waller, who in league with Sanderson had persuaded the Royal Society to stop the publication of Bose's paper, tried also to stop the publication of the paper presented at the Linnean Society in March 1902. Waller's plea was that he had already published this discovery in a journal as early as November 1901. This gave rise to a priority dispute, and Bose asked for an enquiry into the matter. Fortunately fort Bose, he had already dealt with scientific aspects in his Royal-Institution Discourse, which was in print. Moreover, Vines and Howes of the Linnean Society were also Fellows of the Royal Society; they had fortunately seen the proofs of Bose's Royal-Society paper (printed as early as June 1901 but not yet released for publication!). With all the evidence before the enquiry committee, it was established that Waller had plagiarized Bose's scientific results presented before the Royal Society already in June 1901.

Let us recall that at the Royal Society meeting, Waller and Sanderson had vehemently opposed Bose's concept of the universality of electrical response; as leading plant physiologists they had interjected that "there can never be any electrical response* in vegetables". Bose was distressed by the fact that Waller, who had only two years earlier offered to place his laboratory at Bose's disposal and had intended to. collaborate with him, could turn not only an opponent but even a plagiarist !

After Bose's priority was established, Vines wrote to him "There are many queer things you have yet to learn. But I am glad that you now have had a fairplay." Bose was told that his unreleased paper would be published. However, the 'fair play' of the Royal Society did not go beyond the stage of recognizing Bose's priority. The paper remained unpublished all the same.

On the other hand, Bose's paper "Electric Response in Ordinary Plants under Mechanical Stimulation" read before the Linnean Society was published in *Journal Linnean Society* (Vol. XXXV, 1902). Discovery of the similarity of response in inorganic substances and in animal tissues led Bose to the investigation of responsive phenomena in the intermediate region of life of plants. Mechanical response under mechanical stimulus may be obtained in a contractile tissue such as muscle. But in others, nerve for example, stimulus causes no visible change; the excitation of the tissue may, however, be detected by characteristic electromotive changes. The advantage of the electric mode of detection of response is its universal applicability.

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*Waller later published a book, in which he wrote : Previously believed that only sensitive plants gave [electrical] response, "but these notions are to be extended, and we are to recognise that any vegetable protoplasm gives electrical response. I have used all kinds of vegetable protoplasms.

There was no reference there that the 'extension' of 'these notions' was due to Bose. Waller did not even mention that one should 'recog-nise' not only the new finding but also Bose's role in 'recognising' the phenomenon. (See Bose's letter to Tagore, 29 June 1904, Calcutta).

In cases where mechanical response is available, as in the muscle, it is found that records of mechanical and electrical responses are very similar to each other. Burdon Sanderson, Munck and others found electric response to occur only in sensitive plants, e.g. Mimosa. Bose wished to find out whether the responsive electric variation was confined merely to organs (e.g. pulvinus of Mimosa) of plants which exhibit such remarkable mechanical movements, or whether it was a universal phenomenon characteristic of all plants and of all their different organs. His attempt was moreover directed in determining throughout the whole range of response phenomena a parallelism between the animal and the vegetable. He now proceeded to demonstrate that the response given by the plant was physiological and that it afforded an accurate index of the vital activity of the plant. The test applied by human physiologists in order to discriminate as to the physiological nature of the response consists in observing the effects of anaesthetics, poisons, and exceedingly high temperatures, all of which are known to depress or destroy the activity of life. A plant-stalk was mechanically stimulated by torsional vibration, and the intensity of the consequent electric response was recorded. Then Bose applied, on the stimulated stalk, all the above-mentioned inflictions such as the anaesthetic 'chloroform' the poisonous chemical 'mercuric chloride' and high temperatures. The resulting variations of the electric response showed the effects of those inflictions "correspondent to similar phenomena in muscle and nerve" Bose concluded :

> "It has been shown that the electric response is a faithful index of *physiological action* and that such a response is given by, all plants and by their different organs. .....These electric responses in plants fulfil with animal tissues the test of vital *phenomena.*
>
> "The electrophysiological investigation on plants will undoubtedly throw much light on the response phenomena

in the animal. .....In animal tissue ...the vital conditions themselves are highly complex. The essential factors which modify response can, therefore, be better determined under the simpler conditions which obtain in plant life."

It is evident from this paper that although Bose believed in the ultimateness of physico-chemical actions behind all natural phenomena, he did not insist on that point in dealing with similarities between plant and animal tissues. He felt that any attempts at a search for physico-chemical causes behind such organic phenomena would, be premature. Such an ultimate generalization or unification could be achieved only after convincingly establishing the similarity or identity of plant and animal responses in terms of "vital phenomena" or "physiological actions".

After the Royal-Society lecture of June 1901, Bose began to 'feel that for propagating his new findings and ideas he should not' fully depend on the favours of the scientific societies; he must write a book in addition to the papers he sent for favour of publication in scientific journals. The unpleasant incidents that followed the Royal-Society lecture convinced Bose of the need of seeing his book *Response in the Living and Non-living* in print before he returned home. Longmans, Green and Co. brought out this book in the latter half of 1902. In a letter dated 18 July 1902 Bose wrote to Tagore :

"I am busy correcting the last proofs of my book. It will be printed in three or four weeks' time. .....I intended to write in the Dedication Note :

'To my countrymen
Who will yet claim
The intellectual heritage
Of their ancestors.'

But, my Friend, I feel ashamed to write this explicitly. Let my heartfelt intention remain unuttered."

Eventually, Bose phrased it thus : 'To my , countrymen this work is dedicated.' In 1903 Sister Nivedita wrote to Tagore that "the book on Response in Living & Non living is now triumphant". (See APPENDIX - II).

It should be mentioned that in a letter dated 18 January 1902 the Secretairn General of the Society Frankaise de Physique (French Physical Society) communicated to Bose the decision of the Society to elect him a Council Member for three years (1902-1904). Bose visited Paris for a few days in the first week of April 1902 and lectured there at four places. Back in London, Bose came to know about Wallér's plagiarism. Bose experienced pleasantness and unpleasantness in quick succession.

Bose's furlough was to expire by September 1903. Before leaving for home he lectured at the British Association, the Botanical Society and the Royal Photographic Society. The University of Bonn and the French Physical Society also invited him.

Bose returned to Calcutta on 11 October 1903.

VII

Bose, Tagore and Sister Nivedita

THAT WAS THE TIME when India was passing through a new phase of nationalism, which called for outstanding personalities in literature, science and politics. And India also needed their concerted efforts for reviving her ancient glory as a great nation. It was therefore not an accident that bonds of affection and mutual respect brought Tagore, Bose and Nivedita close to one another. History needed them, and their close cooperation also was the need of the times for building a renascent India.

In 1897 Bose and Tagore became friends. Tagore wrote in the mid-1920's :

> "For the first time in my life I tasted the pleasure of friendship when I came into contact with Jagadis. He pulled me out from my groove, just as the radiant splendour of the sun-rise in dewy autumn mornings always forces me out from my bedroom. ...I saw radiance in my friend."

Tagore's insight proved true when Bose emerged as a representative of scientific renaissance in India.

When they became friends, neither of them had attained world-wide fame. Evidently, no careeristic self-interest impelled them towards each other. What really drew them together into close bonds was the fact that both had synthetic minds and both were in quest of an ultimate cosmic unity in the mid of diverse manifestations of Nature. "Another sphere", writes Tagore, "where Jagadis felt an affinity towards me was his profound patriotism." In 1931, on the occasion of Tagore's 70th birthday, Bose reminisced :

"It is more than a third of a century that the Poet Tagore and I have been drawn together in closest bonds of sympathy. His friendship has been unfailing through years of my ceaseless efforts during which I gained step by step a wider and more sympathetic view of continuity of life and its diverse manifestations. .....The barrier which seemed to separate kindred phenomena was found to have vanished, the plant and the animal appearing as a multiform unity in a single ocean of being. ...The same cosmic unity bias unfolded itself to Tagore's poetic vision and has found expression in his philosophic outlook and in his incomparable poems."

Tagore reminisced (January 1938) about his friend just after Bose had passed away :

".....Years ago, when Jagadis Chandra, in his militant exuberance of youthfulness, was contemptuously defying all obstacles to the progress of his endeavour, I came into intimate contact with him, and became infected with his vigorous hopefulness. .....I found in him a dreamer, and it seemed to me, what surely was a half-truth, that it was more his magical instinct than the probing of his reason which startled out secrets of nature before sudden flashes of his imagination. In this I felt our mutual affinity but at the same time our difference, for to my mind he appeared to be the poet of the world of facts that waited to be proved by the scientist for their final triumph, whereas my own world of vision had their value, not in their absolute probability, but in their significance of delightfulness. All the same, I believe that a part of my nature is logical which not only enjoys making playthings of facts, but seeks pleasure in an analytical view of objective reality. I remember often having been assured by my friend that I only lacked the opportunity of training to be a scientist but not the temperament. Thus in the prime of my youth I was

strangely attracted by the personality of this remarkable man and found his mind sensitively alert in the poetical atmosphere of enjoyment which belonged to me."

Thus Bose and Tagore complemented and widened each other's vision of cosmic unity. Nivedita came into their midst at the end of the 1890's as a flame of patriotism and a symbol of rectitude. Nivedita discovered in Bose a rare blend of philosophical outlook with scientific precision. And she found in Mrs. Bose an ideal Indian wife ready to share all tribulations and vicissitudes experienced by her husband. Nivedita realized that Bose, being a scientist with a synthetic mind, was best suited for establishing the claim of renascent India to be a great nation, excelling equally in science and the arts. She indeed saw Tagore as an outstanding national celebrity. However, she felt an urge to be a close friend of his, especially because he was an intimate friend of Bose.* Although Nivedita made the acquaintance of the Boses a year after Tagore had come into contact with them, it was she whom Tagore once requested to write for him a coherent "account of the actual discoveries which Prof. Bose had made, & of the difficulties under which he had laboured in making them." (See-Appendix — II).

Tagore's early friendship with Bose is described by the poet's son Rathindranath thus :

"The attachment of the scientist, and the poet was much more than just friendship. They would constantly exchange ideas. One would talk of the next story to be written and the other of the remarkable results obtained from experiments carried on in his laboratory. They would not only appreciate each other's criticism but derive inspiration from their

*Nivedita wrote to Tagore (16 June 1899, Calcutta) "...I really wanted to add a new friend to those with which India has already - blessed me, and you are so dear to my friend Dr. Bose, that I cd. not help hoping you sd. be my friend too! ..."

> discussions. Every week-end that Jagadis came to Shilaidah [the poet's resort in East Bengal, now Bangladesh, on the bank of the Padma] he would make Father read out to him the short story that he had written the previous week and get a promise from him to have another ready the next week-end His constant demand from his friend made Father write so many short stories at this period."

We may recall how at Bose's instance Tagore composed the poem on Karna, the wronged hero of the. Mahabharata.

Bose and Tagore were always ready to help each other in hours of need and tribulations. Towards the end of 1900, when Bose was in England, he wrote to his poet friend that the new line of scientific research pursued there would remain unfinished, because his deputation-leave was to expire "before the Easter' of 1901 (see foregoing chapter). Tagore immediately assured him in a letter dated 12 December 1900 :

> "...Are you not entitled to unpaid furlough? .....Anyhow, you must not return home leaving your work incomplete. Don't let your work suffer. I shall take up the responsibility of relieving you of financial worries."

Tagore further asked (21 May 1901) Bose to give him unhesitatingly and frankly an estimate of the financial help that would be needed for his stay in England for five or six more years. The subsequent history of how Tagore received that estimate from R. C. Dutt and freed Bose of financial worries has been already narrated.

At the very time when Tagore was doing all that was needed for an unimpeded completion of the research of his scientist friend in England, Bose on his part strongly felt that he must try his best to bring his poet friend out from obscurity, and popularize his short stories among British readers through translated versions. Bose wrote :

".....I won't allow you to live in the obscurity of rural life. .....I must publish your stories in this country [England]. .....You must realize that you are a citizen of the world. .....I want to see you honoured as a celebrity."

Bose did have quite a few of Tagore's short stories translated into English by Nivedita and some other British friends. The translated stories (in the manuscript form) moved such sensitive intellectuals as Prince Kropotkin — an admirer and friend of Bose, but western periodicals like Harper's Magazine showed utter lack of interest in publishing stories concerning oriental life. Although Bose's efforts to popularize Tagore among western readers had failed at that time, the same translated stories were eventually published when Tagore attained world fame about a decade later. In 1913, when Tagore was awarded the Nobel Prize, Bose wrote to him :

> "I always felt unhappy at not seeing you decorated with a victory garland. Today I am free from that unhappiness."

Tagore on his part immortalized Bose through many essays and poems. To mention a few, Tagore, as the editor of *Barigadarsam* (edited earlier by the late Bankim Chandra Chatterjee) as well as Bhandar, wrote a series of popular articles on Bose's researches and achievements in those periodicals, so that educated lay readers of Bengal could understand the essence of those investigations and could thereby realize the importance of his work in the world of science. Tagore composed quite a few poems in praise of Bose, among which two are remarkable—one composed in 1901 and the other in 1906. (Their translated versions are reproduced in APPENDICES—III & IV). What prompted Tagore to compose a poem on Mimosa becomes evident from the role this plant played in Bose's plant physiological researches. It is also noteworthy that in 1913 Bose presented Tagore with a potted Mimosa—a symbol of sensitivity—while felicitating him at Santiniketan on his receiving the Nobel Prize.

When Bose founded the Bose Institute in 1917, Tagore composed an inspiring inaugural song at his friend's request. In 1922 Tagore made Bose the Vice-President of his newly founded international university, the Visva-Bharati. In 1928, when Bose completed seventy, it was Tagore who took the initiative in celebrating that occasion befittingly. And in 1931, when Tagore completed seventy, Bose was one of the sponsors who brought out the *Golden Book of Tagore* edited by Ramananda Chatterjee. Thus these two friends always desired to associate each other with whatever they prized most.

Sister Nivedita played an inspiring role in the life of Bose, and on her part she saw him as a "great, spiritual mariner" — a "Columbus" — "who found new worlds" through his borderland scientific researches. Nivedita dreamed of the establishment of a scientific research institute epitomizing the renascent wisdom of India. She believed that Bose was capable of founding such an institute. The institute came into being in 1917, but Nivedita had passed away in 1911 in Bose's summer resort at Darjeeling. In the inaugural address at the Bose Institute, Bose said :

> "In all my struggling efforts I have not been altogether solitary; while the world doubted, there had been a few, now in the City of Silence, who never wavered in their trust."

Bose's tribute to her memory is enshrined in the impersonal bas-relief in bronze placed above the lotus-pool at the entrance to his Institute. Bose writes :

> "Entering the Institute, the visitor finds to his left the lotus fountain with a bas-relief of a Woman Carrying Light to the Temple. Without her no light can be kindled in the sanctuary. She is the true light-bearer, and no plaything of man."*

*Tagore wrote just after Bose's death : "He [Bose] was fortunate in finding in Sister Nivedita a great inspiration to all his activities and creative work. The name of this noble lady deserves a respectable place in the chronicle of Jagadis Chandra's life-work. Her pervasive influence induced him to overcome all obstacles, his being spreading out over the world to play a universal role."

Mrs. Bose looked up to Nivedita "as a woman ...full of austerity and possessed with a longing for righteousness which shone round her like a pure flame".

Nivedita introduced to the Boses an American lady Mrs. Sara Chapman Bull, who like her Irish friend Miss Margaret Noble (Nivedita) became a follower of Swami Vivekananda. Just as Bose found in Nivedita an inspiring sister, he found in Mrs. Bull a loving mother. What role they played in seriously trying to establish Bose's priority in inventing the galena detector is described in the following chapter.

In this connexion it may be mentioned that Swami Vivekananda, who on his way back home from the West happened to be present at the International Congress of physicists of 1900 in Paris, became a great admirer of Bose and hailed him as a "heroic son" of India. By an irony of circumstance Nivedita, a devotee to Vivekananda, severed her connexions with the Ramakrishna Mission within a week after her guru's death (1902), and breathed her last (1911) under the roof of the savant whom her guru had extolled as a "heroic son" of India.

Vivekananda felt that Bose must not fritter away his energies in the stereotyped political movements that drew many talented minds of the time into their vortex. He urged Bose to devote himself wholly to scientific researches. This, the monk felt, would enable Indian nationalism to manifest itself as brilliantly in the field of science as in social and cultural fields. It is thus the fire of nationalism that strengthened the bond between the Brahmo scientist and the Hindu friar.

VIII

Galena Receiver

WE MAY RECALL THAT at the Royal Institution Discourse of May 1901 Bose demonstrated an "artificial retina". It has been mentioned why Bose at that time chose to be reticent about what it was essentially made of. He stated that his "artificial retina" or "sensitive receiver" could "see lights not only some way beyond the violet, but also in regions faze below the infra-red, in the invisible regions of electric rediation. It is in fact a *Tejometer* (Sanskrit tej-radiation), or universal radiometer". But he did not explicitly mention that the "sensitive receiver" was a pair of galena point-contacts — the first* semiconductor receiver of radio waves. He described the other components of the artificial retina in detail, and but for a wireless tycoon's persistent, attempt to patent it for making money Bose would have certainly uttered the name of the essential component.

Although Bose himself felt a strong repugnance to the commercialization of science, he was made aware of the prevailing situation by Nivedita and Mrs. Sara Bull. That was the time when Marconi had already secured (April 1900) a wireless patent, well known as the 'Four-sevens' patent. Marconi's lead in the race heightened the patenting psychosis even among such academicians as Oliver Lodge, who in collaboration with Muirhead formed the Lodge-Muirhead Syndicate in 1901. Earlier, they had applied (1897) for patents after knowing of

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*Although at a Friday Evening Discourse of the Royal Institution in 1876 C. W. Siemens had spoken on the Action of Light on Selenium and had constructed a so-called "artificial eye" of selenium, the question of using it as a wireless detector did not arise, because Hertz discovered radio waves in the late 1880's.

Marconi's application for the first wireless signalling patent in June 1896. In such a situation Nivedita and Mrs. Bull felt that Bose should not lose the priority-race simply by default. That was the reason why they persuaded him to apply for a U.S. Patent in September 1901, i.e. within a few months after his lectures at the Royal Institution (May 1901) and Royal Society (June 1901), where he had described the galena receiver. They knew quite well that Bose would not reap any profit from the patent, but they desired that Bose's priority in devising a unique type of wireless detector should be recorded in the chronicle of science. A patent would be a permanent record of that priority.

Bose therefore applied for a patent in September 1901, and the U.S. Government granted it in March 1904. But after securing it he allowed the patent to lapse. He. cherished the ideal of ancient Indian scholars and sages, who — though patronized by affluent kings — disliked the idea of making money beyond what plain living called for. This philosophy of life is reflected in Bose's inaugural address on the occasion of the foundation of the Bose Institute in 1917

> "Through the regular publication of the Transactions of the Institute, ...Indian contributions will reach the whole world. The discoveries made will thus become public property. *No patents will ever be taken.* The spirit of our national culture demands that we should ever be free from the desecration of utilizing knowledge for personal gain."

The heading of the text of the Patent reads thus : "United States Patent Office, Jagadis Chander Bose, of Calcutta, India, Assignor of One-half to Sara Chapman Bull, of Cambridge, Massachusetts. — *Detector for Electrical Disturbances.* Specification forming part of Letters Patent No. 755840, dated March 29, 1904. Application filed September 30, 1901. Serial No. 77028 (No model)." Bose signed the five-page Patent in the presence of two subscribing witnesses R.E. Ellis & T.L. Whitehead.

Here is a simplified, legended diagram of the galena detector.

In describing the detector, Bose wrote :

> 'By placing an ordinary glass lens .....in the opening in the wall of the case-section .....opposite the sensitive contacts .....of the instrument and by throwing light upon this lens an immediate response is observed in the galvanometer, the needle of which is deflected in accordance with the spectral properties of the light thrown upon the sensitive contacts or artificial retina. With a glass lens the instrument will detect and record lights not only some way beyond the violet, but also in regions far below the infra-red in invisible regions of electric radiation. We may thus style the apparatus a 'tejometer' (Sanscrit tej=radiation) or universal radiometer. .....By removing the metallic and wooden casings and lens the instrument may be used as a detector or so-called 'coherer' for, wireless or other telegraph. .....What I claim, and desire to secure by Letters Patent is — .....a coherer or detector of electrical disturbances, Hertzian waves, light waves, or other radiations, comprising a pair of galena contacts....."

In a technical review of semiconductor research, W.H. Brattain, a Nobel-Prize winning (1956) pioneer of the physics of semiconductors and transistors clearly indicates Bose's priority in introducing a semiconductor as sensitive radio-wave detector. Brattain writes (1955) :

> "The demonstration of the existence of radio waves by H. Hertz in 1888 created a potential demand for a suitable detector, but it was not realized until 1904 that semiconductor rectifiers were well suited for this purpose. J. C. Bose [11], H.H.C. Dunwoody [12], L. W. Austin [13], and G. W. Pierce [14] found that point contacts (cat whiskers) on galena, silicon carbide, tellurium, silicon, etc.,

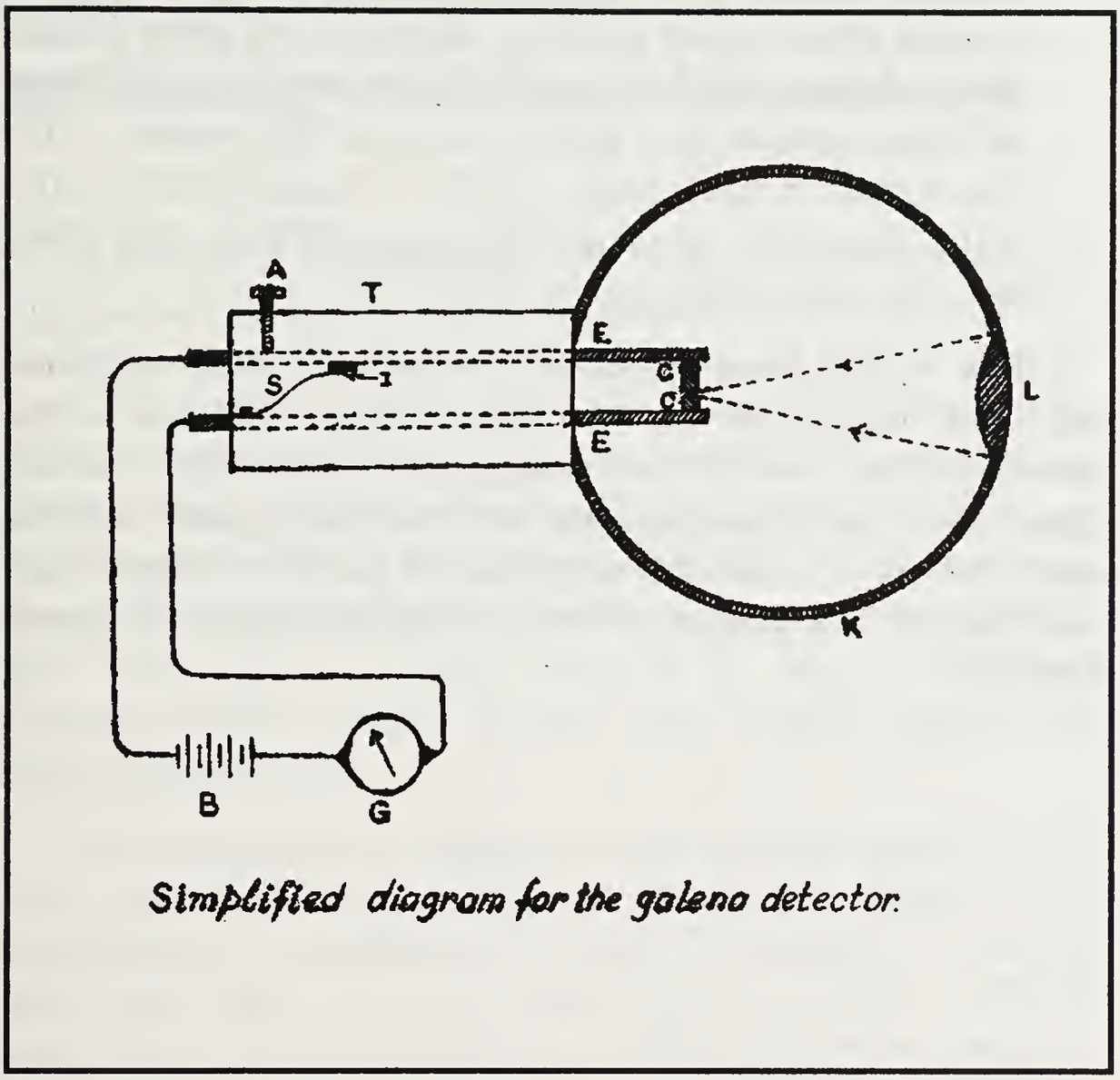


Figure 2

CC, sensitive contacts (galena); A, micrometer screw for adjusting pressure on the spring (S) in order to vary the force of contact between CC; EE, electrically' conducting arms, movable through the tube (T) for focussing CC with respect to the lens employed (L); I, insulating surface; K, casing; B, battery; G, dead-beat D'Arsonval galvanometer.

were good detectors of radio waves. Silicon detectors were found by experience to be most stable, while galena detectors had the best sensitivity. ...With the advent of the vacuum tube at about this time, interest in the point contact detector lagged and little of scientific interest was contributed on such detectors for a number of years. (References : [11] US—Patent 755840, 1904, [12] US—Patent 837616, 1906; [13] ...Phys. Rev. 24 (June 1907), pp. 508-510; [14]..Phys. Rev. 25 (July 1907), pp. 31-60...)"

It is evident from above why semiconductor research had remained neglected for decades since 1904, and the transistor-effect was discovered only in the late 1940's. Viewed against this science-historical perspective, Bose's galena detector stands out as a remarkable exemplar of modern technological contributions. His galena detector was the forerunner of crystal detectors.

IX

From the Borderland of Physics and Biology to Plant Physiology

IN MAKING A COMPARATIVE study of the responses of organic and inorganic matter, Bose based himself on Waller's assumption that "the most delicate sign of life is electric response". (See Chapter VI). From the observed fact that living tissues exhibit electrical response, it had been concluded by scientists that this phenomenon of response was peculiar to living organisms. But Bose's demonstration of the "general resemblance" of the response (see the diagram) of his "artificial ratina" and that of a frog's retina at the Royal Institution Discourse of 1901 pointed to some kind of unity between the living and non-living.

He incorporated his findings in the book *Response in the Living and Non-living* (1902), as mentioned already. The demonstration of similarities between the responses of living tissues and those of twisted metal wires or of the artificial retina* was a pioneering attempt by Bose to devise inorganic models which simulate some of the characteristics of electric response of living tissues. In this respect he deserves to be considered an anticipator of cybernetic devices or automata.

As already mentioned in Chapter VI, the "discovery of the similarity of response in inorganic substances and in animal

*Bose constructed another kind of so-called "artificial eye". It was a cup-shaped silver plate, whose inner surface was sensitized by bromine vapour. This was filled with water, and electric connexions were made to a galvanometer; one end dipped in the water, and the other was connected to the silver plate.

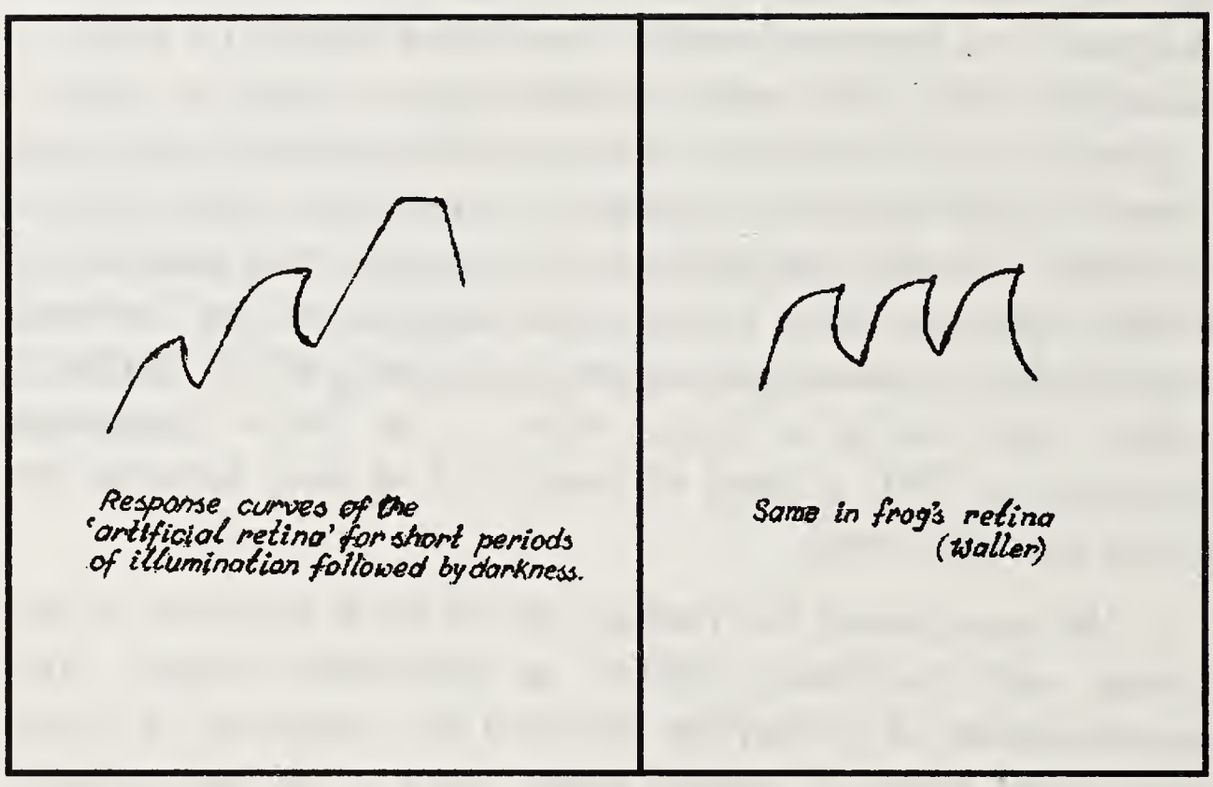


Figure 3

Two sets of response curves

tissues led me", writes Bose, "to the investigation of responsive phenomena in the intermediate region of life of plants". We have seen how the subsequent experimental results and their interpretations gave rise to controversy between the leading British physiologists and Bose.

In 1906 Bose brought out the book *Plant Response* as a *Means of Physiological Investigation*. There he incorporated all the findings that, according to him, pointed to a fundamental unity of cellular organization in plants and animals.

In making these investigations, Bose used a large variety of plants, including ordinary plants and also sensitive plants with motile organs (such as Mimosa pudica or 'lajjavati', Biophytum sensitivum, Desmodium gyrans, etc.). He employed stimuli such as (i) mechanical — friction, torsion, prick, etc.; (ii) chemical — application of inorganic poisons like copper-sulphate, potassium cyanide, etc. and organic substances like chloroform, ether, etc.; (iii) thermal — application of radiant heat from electrically heated wires; and (iv) electrical — make or break of steady currents, rapidly interrupted currents, etc. Bose showed that like the sensitive plants, ordinary plant tissues also exhibit excitatory electrical response as well as mechanical response to stimuli. Then he focussed his attention on some important characteristics (contractility in muscular organs, conductivity of nerve excitations and rhythmicity or 'spontaneous movements') of animal tissues and showed that "there is no physiological response given by the most highly organised animal tissue that is not also to be met within the plant". Bose regarded the pulvinus of Mimosa as functionally similar to an active animal muscle, and he believed that "the functional similarity between the two contractile organs, pulvinus and muscle, is not confined to the manifestation of outward movement, but can be traced to the ultimate protopolasmic mechanism". As to the Characteristics of the conduction of nervous excitation too, Bose believed that the

cellular protoplasm was the basic substance governing excitatory transmissions in both the animal and plant. He suspected that there must be, in plants, some specialized tissues associated with the conduction phenomena, just as there are nerves in animals. He was the first to use an electric probe of fine platinum wire (for introducing into different depths of the plant stem) for finding and locating the specialized plant tissue comparable with animal nerves. Although Bose indentified the phloem as the 'nerve' of the plant, this finding is not confirmed by independent investigations. Even Bose's admirer Prof. Hans Molisch, a well-known plant physiologist of the University of Vienna, commented in the foreword to the German edition (1928) of Bose's book *Plant Autographs and their Revelations* : "Only future can tell whether this view of the author [about the phloem] will succeed or will be superseded by another." However, the application of the electric probe represents the introduction of a new experimental technique which is utilized elsewhere.

It is true that some plant physiological investigations of Bose have not stood the test of reproducibility through independent researches. Nevertheless, it must be emphasized that he dispelled considerably the prevailing idea that some inscrutable, extraphysical 'vital force' separates the organic from inorganic and that the life-processes in plants and animals are essentially distinct. Let us recall that Bose himself used the terms "vital phenomena" or "physiological actions" in investigating the similarity of plant and animal responses. But he did not use these terms in an obscurantist way; he reiterated his belief that the intricate mechanism of life will probably "some day be ultimately traced to physico-chemical reactions". In the preface to the book on *Plant Response* he clearly wrote :

> "I have attempted to show that the plant may .....be regarded as a *machine*, and that its movements in response to external stimuli, though apparently so various, are ultimately reducible to a fundamental unity of action." (italics mine)

In dealing with rhythmicity or "so-called spontaneous movements" (e.g. pulsating movements of tissues) of plants, he clearly stated that strictly speaking there were no such things as "spontaneous movements". These were "really due to external stimulus previously absorbed by the organism". He emphasized that in dealing with the "phenomena of life" one should not postulate the existence of a special kind of force "which would interfere with that law of the Conservation of Energy which is known to hold good in the inorganic world". Bose was indeed critical of those who refused to see any essential similarity in the life-mechanism of the plant and animal; but he was as much critical of those who went to the other extreme. He said :

> "There are some, on the other hand, who without any proof, but through more sentimentality, attribute to plants even human qualities. But these imaginings cannot in any way advance exact knowledge. The similarity, if any, between plant and animal life can only be established by demonstrating the unity of physiological mechanism in all life."

In 1907 Bose's book *Comparative Electrophysiology* came out, through which ".....a deeper perception of unity (of physiological mechanism of plant and animal) has been made available", and "many regions of inquiry have been opened out which had at one time been regarded as beyond the scope of experimental exploration". In this book Bose introduced a chapter on 'Memory' and dealt with some psycho-physical aspects of plant-physiological phenomena. Bose's early characterization of the plant as a "machine" and his attempt to associate some features of "memory" with plant-physiological mechanisms certainly earn him the honour due to a pioneer in the study of cybernetic systems. Comparative Electrophysiology was translated (by Pierre Lehmann) into French, 'Electro-physiologie Comparee', about two decades later and was published by Gauthier-Villars & Co. (1927).

We may recall that Bose had expressed in 1901 his desire in a letter to Tagore from London that he must go abroad every third year to propagate his scientific views. He then returned home in October 1903. Now, in 1907 it, was felt not only by Bose himself but also by such eminent public-spirited men as Gopal Krishna Gokhale that the new plant-physiological researches should be presented before Western men of science. The Government of India sent Bose on his third scientific deputation to Europe and the U.S.A. He started for Europe in September 1907 and spent about a month in Germany for the treatment of some ailments. He reached England by early December.

In Dublin, Bose read a paper on "Mechanical and Electrical Response in Plants" at the British Association. Then he visited (1908-1909) America, where he lectured on plant physiology at many places such as the American Association for the Advancement of Science (AAAS), the Botanical Society at Baltimore, the Medical Society of Boston, the Chicago Academy of Sciences, the Torrey Botanical Club, the Western Society of Engineers at Chicago and at the Universities of Illinois, Ann Arbor, Wisconsin and Chicago. As to his lecture at the AAAS at Baltimore, he writes to Tagore (dated 8 January 1909, Cambridge, Massachusetts) :

> "They all have expressed appreciation and amazement. At many places, new researches have been started with the help of instruments devised by me. The Agricultural Department of Washington invited me. .....They expect many concrete results from my investigations."

Here, Bose's reference to his instruments shows that by that time he had devised some reliable pieces of apparatus. In dealing with different life-processes of Plant he ".....came to recognise

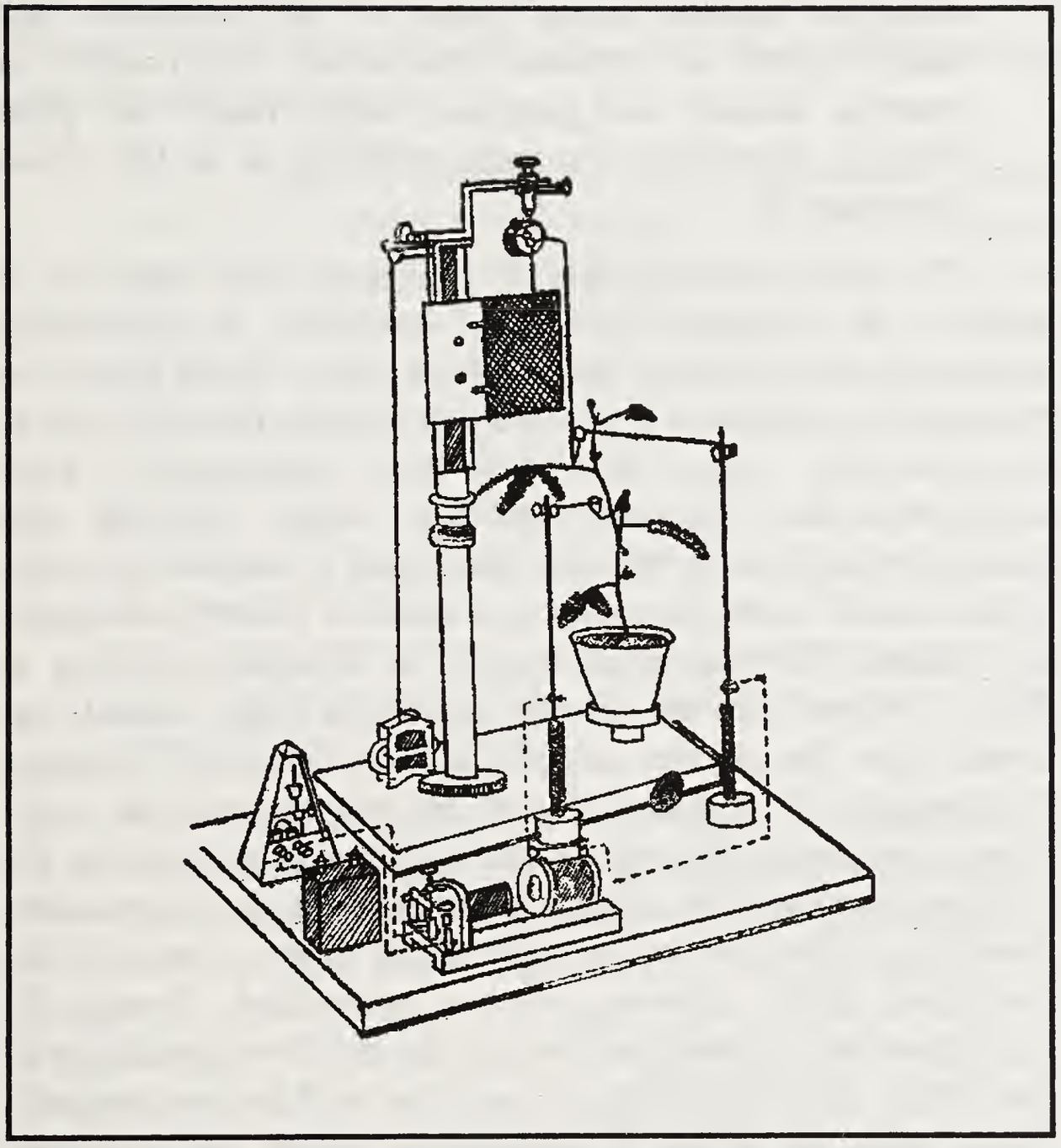


Figure 4

Resonant Recorder with a Mimosa plant

> that the main difficulty which stood in the way of deeper knowledge was the absence of sufficiently sensitive means of detecting the internal activities of plant life. I therefore devoted many years to the invention and construction of various Automatic Recorders of extreme delicacy and precision, which enable the plant itself to write down the inner workings of its life." (See Appendix-V)

The exact determination of extremely short intervals of time is an important problem, especially in measuring time-relations of different phases of response of living tissues. In the sensitive Mimosa, it is necessary to measure time-intervals as short as -001 second. For such time measurements, Bose constructed the 'Resonant Recorder', which indicated that excitatory impulses in Mimosa (analogous to nervous impulses in the animal) were transmitted at a speed of 20-400 millimeters per second. The velocity of impulse in Mimosa, according to Bose, is slower than the nervous impulse in higher animals but quicker than that in lower animals. Bose constructed a 'Resonant Cardiograph'. By means of this he not only recorded the heart-beats of animals with great precision, but also showed that the depression produced in animal cardiac pulsation due to potassium bromide solution and its stimulation due to the extracts of the medicinal plant *Abroma augusta* resembled closely the corresponding response patterns of the rhythmic pulsations of the leaflet of *Desmodium gyrans* (the well-known telegraph plant) under the action of the same depressant and stimulant. According to Bose, an isolated leaflet of the telegraph plant exhibited a considerable similarity to a pulsating animal heart, just as a pulvinus of Mimosa resembled an animal nerve-muscle unit (the phloem inside the pulvinus of Mimosa was characterized by Bose as the specialized channel for the transmission of 'nervous' excitations or irritations).

Bose devised the 'High Magnification Crescograph' for measuring the growth rate of plants. According to him, external agents and stimuli (such as exposure to wireless waves) modify the regular increase in length of growing plant stems. The average rate of the regular plant-growth is about 1/100,000 inch per second. Bose writes :

> "Even with the magnifying growth recorders hitherto employed it takes a very long time to detect and measure its rate. For accurate investigations on the effect of a given agent on growth, it is necessary to keep all other variable conditions, such as light and warmth, strictly constant during the whole period of the experiment. ...Experiments which require several hours for their completion are, therefore, subject to serious errors which vitiate the results. The only satisfactory method is one that reduces the period of the experiment to a few minutes; that, however, necessitates the devising of an apparatus for exceptionally high magnification, and for the automatic record of the magnified rate for growth."

Bose's High Magnification Crescograph instantly records, at a magnification of 1000 times, the imperceptible growth and the variation induced in it under chemical or electric stimulation. His 'Balanced Crescograph' enables a direct determination of the change in growth rate of a plant under stimulation. The magnification is considerably increased by the `Magnetic Crescograph', which produces a magnification of about 10-50 million times. Bose commented thus on the usefulness of the crescograph :

> "Authorities expect this method of investigation will advance practical agriculture, since for the first time we are able to analyse and study separately the conditions which modify the rate of growth."

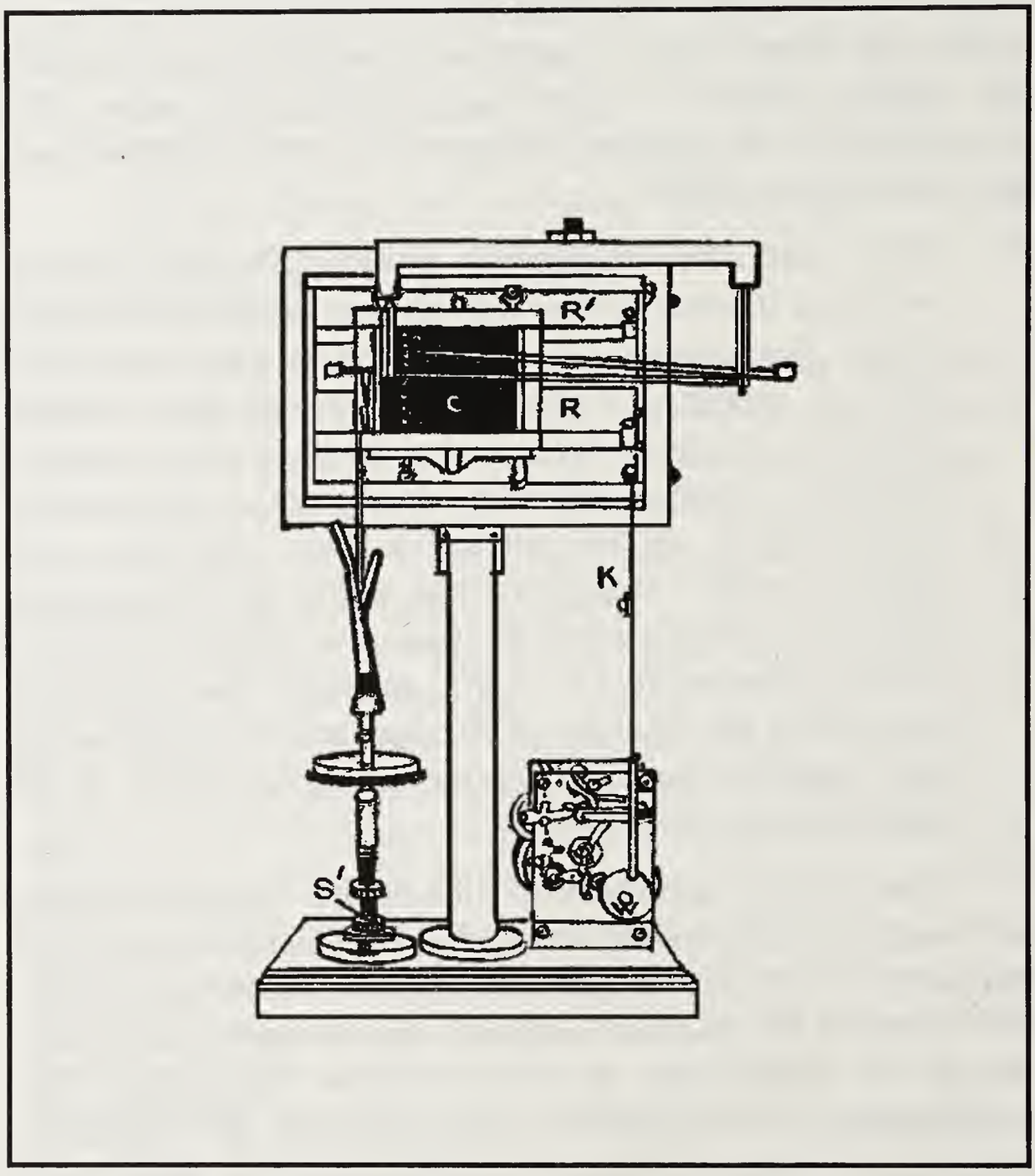


Figure 5

High Magnification Crescograph

P, plant; W, rotating wheel with clockwork for periodic oscillation of recording smoked glass plate. C; S.S. micrometer screws. K, crank; RR eccentric

Bose later devised a 'Photosynthetic Recorder' which automatically imprints on a moving drum the normal rate of carbon assimilation of aquatic plants. It also records changes in that rate induced by infinitesimal traces of chemical substances such as formaldehyde. It is noteworthy that Bose accurately determined the efficiency of the photosynthetic organ in storing solar energy. By 'efficiency' is meant the ratio of the energy stored to the energy absorbed. He found the efficiency of the photosynthetic organ "to be much higher than had been usually supposed, being half that of an ordinary steam engine. In vigorous Hydrilla plant [an aquatic plant] it is as high as 7.4 per cent". He anticipated the possibility of harnessing the solar energy absorbed photosynthetically by plants.

Inquisitive readers may look up Bose's *Collected Physical Papers* for other devices such as the 'Self-recording Radiograph', 'Magnetic Radiometer', etc.

By mid-1909 Bose returned home from abroad. Back in India, he carried on his specialized research in plant physiology. At the same time, he was always ready to disseminate, among the lay public of his own country, his scientific views in a remarkably lucid style and non-technical language. This aspect is discussed in Chapter XII. His outstanding researches earned him in 1912 a D.Sc. (Honoris causa) of the University of Calcutta, and also the imperial honour, 'Companion of the Star of India' (C.S.I.), just as in 1903 the order, 'Companion of the Indian Empire' (C.I.E.) had been conferred on him.

1913 saw the publication of his book *Researches on Irritability of Plants*, which described the Resonant Recorder, the physiological characteristics — contractility, conductivity and rhythmicity (see above), and the effects of drugs and antidotes on rhythmic tissues in animals and plants. This book evoked great interest among Western men of science, and he received invitations from different scientific societies of Europe

for delivering lectures. The Punjab University also invited him the same year to deliver three lectures. He was offered an honorarium of Rupees 1200 by that university for his lectures, but he endowed the whole amount as research scholarship for the same university.

In 1914 Bose was sent by the Government of India on his fourth scientific deputation. The mimosa and telegraph plants he had carried with him in addition to his instruments were housed in a tropical greenhouse in London. A laboratory was also set up there. One day Sir William Crookes visited Bose's laboratory and explained to him frankly that his casting vote as the President of the Royal Society had prevented the publication of his papers on plant response in the Proceedings of the Royal Society. Crookes confessed that he had considered Bose's borderland investigations to be metaphysical speculations inspired by "oriental imagination", but now he realized the soundness of those investigations. Thus a decade-long misunderstanding between Bose and the Royal Society was dispelled. During the period 1914-15 he was invited by the Royal Institution for the third time to deliver a Friday Evening Discourse. At the Royal Society of Medicine, London, he lectured on "The Action of Drugs on Plants".

Referring to this scientific deputation Bose says :

> "At that time my experiments were demonstrated in London, Oxford, Cambridge, Paris, Vienna, Harvard, New York, Washington, Philadelphia, Chicago, California, Tokyo, etc. None in those places waited for me with victory garlands. On the contrary, my powerful opponents came in a body to find fault with me. ...In this unequal battle, India triumphed, and my one-time opponents became my close friends."

In this connexion, let it be mentioned that two renowned German authorities on plant physiology, Haberlandt and Pfeffer, had not accepted Bose's theory that the transmission of excitation

in plants was analogous to nervous transmission in animals. During his fourth scientific mission, Bose wanted to exclude Leipzig from his itinerary but eventually did not. The reasons are evident from what he himself said about it :

> "Much of the great advances in modern plant physiology is due to the remarkable investigations made by Prof. Pfeffer of Leipzig in the course of half a century. Some of my discoveries contradicted his views. Believing to have incurred his displeasure I bypassed Leipzig and visited the Vienna University in response to its invitation. Pfeffer sent his colleague to Vienna in order to invite me to Leipzig. Pfeffer conveyed to me his regret that my new theories reached him very late in his life. He regretted further that he won't live to see the ultimate triumph of all these truths. I was received as a friend by one, from whom I had expected enmity. This is an example of noble heroism which enables one to see the triumph of truth even in one's own defeat and feel elated. This ideal of heroism was preached three thousand years ago at Kurukshetra. When the fiery arrow pierced Bishma's heart, he was overwhelmed with emotion and said, 'The training I gave has borne fruits. This arrow is not from Sikhandi, but from my favourite disciple Arjuna.'..."

In America, Bose's lecture-demonstrations on plant response convinced agricultural scientists of the practical benefits obtainable from his plant-physiological researches. *The New York Tribune commented* (10 January 1915) :

> "What is the value of this knowledge? asks the practical man. It has a very definite value, according to Professor Bose. ...The knowledge gained may. ...be applied in the study of the effects of poisons, and antidotes may be discovered. The plant experiments not only show how poisons work, but it has been discovered that antidotes will

revive the plants after trying experiences with the poisons. In experimenting with a new poison, therefore, the door apparently is opened to the discovery of antidotes".

And no less a scientific journal than *Scientific American* (April 1915) remarked on Bose's work and his crescograph :

"By a remarkable series of experiments conducted with instruments of unimaginable delicacy, the Indian scientist has discovered that plants have a nervous system. His experiments promise not only to revolutionise plant physiology but to open great new fields of experimentation in applied science such as Medicine and Scientific Agriculture ...What is the tale of Aladin and his wonderful lamp compared with the possibilities of Dr. Bose's crescograph? In less than quarter of an hour the action of fertilizers, foods, electric currents and various stimulants can be fully determined."

(Bose himself observed that, "These investigations might lead to the increase of earth's food supply".)

Thus Bose's achievements were recognized abroad with great eclat. Back in India he received an honour that was unique in the history of the Indian Educational Service. He was to have retired in 1913. But in recognition of his outstanding services to the Presidency College as a teacher and researcher, the period of his service was extended by two years, i.e. he retired in November 1915. Furthermore, the government gazetted him as Emeritus Professor on full pay for five more years.

During 1915-17 Bose pursued his investigations in his research laboratories and plant nurseries (cum retreats) at Sijberia on the Rupnarayan, at Falta on the Ganges and at Darjeeling. However, for a long time he had been feeling the need of establishing a research institute modelled after the Royal Institution of Great Britain. He had experienced great difficulties in carrying on scientific work owing to the absence of a well-

equipped laboratory in his own country. He had known the stepmotherly attitude of our universities towards research work. In reviewing the state of higher education in Bengal, Bose observed (1913) :

> "The object of a University being the advancement of knowledge, this must include the complementary functions of the discovery of truth and diffusion of knowledge. It may be said generally that teaching degenerates, unless it be kept in touch with research; since the constant repetition of second or third-hand knowledge leads to mere mimicry in pupils, the living touch of reality is lost."

Bose knew that there was "a genuine desire among a fair number of students to undertake research work", but lack of opportunities for research in our country caused a constant export of students to foreign universities, which offered such facilities. He believed that India on her part would attract even foreign researchers, if a "Temple of Learning" could be founded with opportunities for carrying on researches in the borderland of physics, physiology and psychology. "This is not to be regarded as an unrealisable dream. It has been accomplished before. The fame of Nalanda and Taxila did attract students from other lands who made long pilgrimages to the Indian shrines of learning." Bose felt that "the greatest work for the future lies in the, borderlands"; and that the Indian mind, being "characteristically synthetic", was pre-eminently capable of striking out a new path in the borderlands.

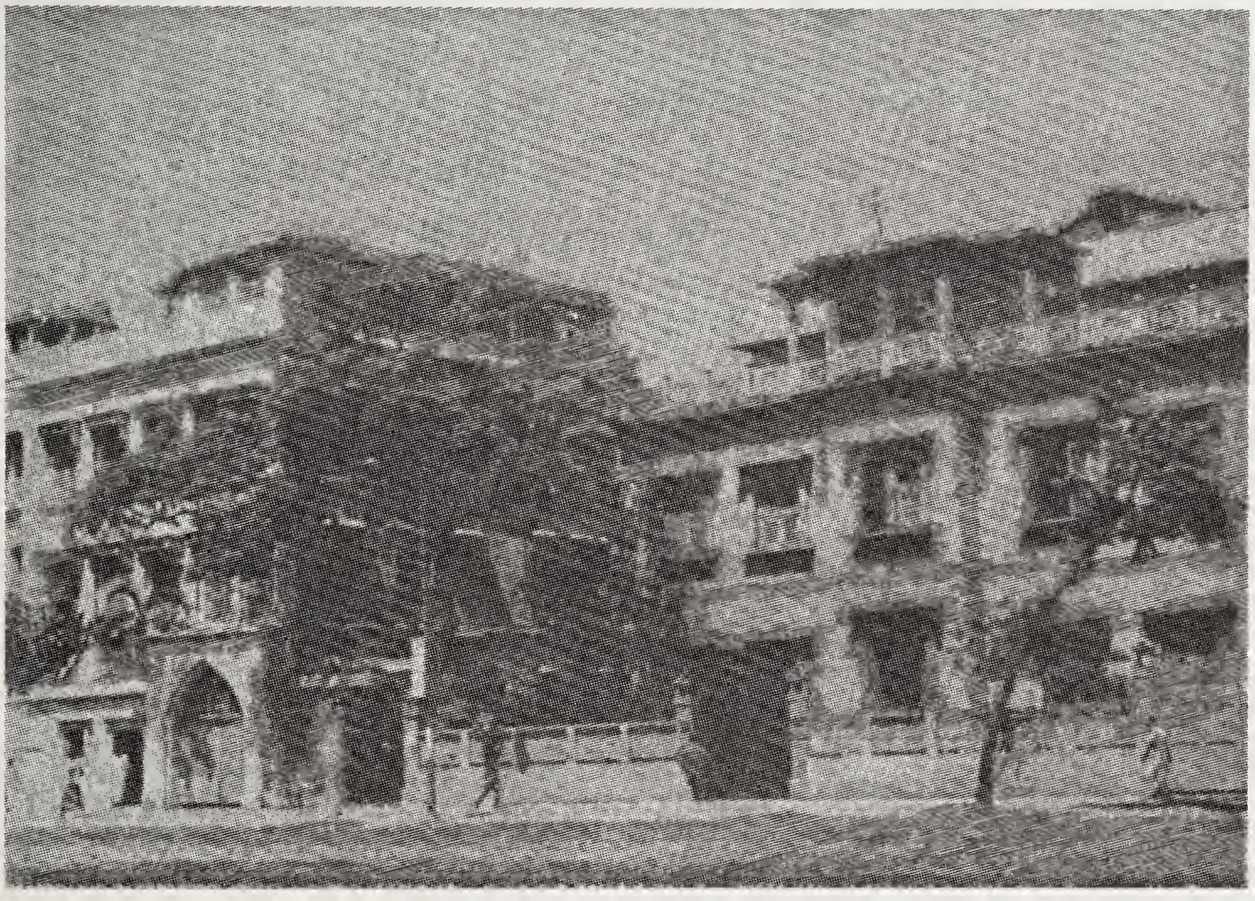
X

For a Synthesis : The Institute

BOSE HAD DREAMT OF establishing an institute, where through a fruitful blend of the analytical scientific method of the West and oriental imagination, we would some day arrive at a grand synthesis of seemingly diverse disciplines of knowledge. This dream was realized on 30 November 1917, his fifty-ninth birthday. The Bose Research Institute came into being.

For that occasion the inaugural song was composed by Tagore, and the famous artist Nandalal Bose came up with a painting. Nandalal's masterpiece, decorating a wall of the lecture-hall, symbolizes "The Quest : Intellect aided by Imagination". `Intellect' starts from the sacred river and strides forth. His hand feels the sharpness of the sword-edge with which he has to cleave his way. He is companioned, in his adventurous quest, by his bride, `Imagination'. The melody of her magic flute inspires him in his journey towards the unknown. The auditorium, which can seat about 1500 persons, is a fine blend of an aesthetically pleasant Ajanta motif with a perfect acoustics typical of scientifically constructed modern lecture-halls. Moreover, the building for accommodating professors and research scholars manifestly bears the stamp of an architectural motif adapted from Ajanta. Thus Bose's desire for reviving the synthetic philosophical wisdom of India found expression not only in the subtle intellectual spirit underlying the Institute, but also in the tangible artistic construction and embellishment of the buildings that constitute the Institute.

The Institute was started with ten scholars and research assistants, eight trustees (e.g. Tagore, Lord S.P. Sinha, Mrs. Abala



Bose Research Institute

Bose, Dr. Nil Ratan Sircar, etc.), nine board-managers, two visitors (Lord Ronaldshay & Sir Manindra Chandra Nandy), and eight honorary members (e.g. Lord Rayleigh, Sydney Vines, P.C. Ray, Patrick Geddes, R.A. Millikan of Chicago University, R.A. Harper of Columbia University among others). Bose collected for the Institute donations amounting to several lakhs of rupees from the public. The Government of India generously sanctioned grants "towards placing the Institute on a permanent basis". Bose said gratefully in his inaugural address : "Out of many who would feel an interest in securing adequate Endowment, the very first donations have come from two of the merchant princes of Bombay, to whom 'I had been personally unknown." Thus Bose could "combine scientific renown", remarked Tagore, "with a vast material means adequate enough to build this Institute, one of the very few richly endowed mediums in India for bestowing the benediction of science upon his countrymen". It should be mentioned that Mahatma Gandhi's earnest appeal to the public of Bombay secured substantial donations from that great city.

Bose's inaugural address of 30 November 1917 is a fine exemplar of inspired speech. In dedicating the Institute to the nation, he referred to it as "not merely a Laboratory but a Temple", where the teachers and scholars, untrammelled by mundane distractions and temptations, would ceaselessly pursue their, quest for truth.

He narrated how his early researches in Hertzian waves won him laurels and recognition from the Royal Society, how he was "unconsciously led into the border region of physics and physiology" and lost favour` with the Royal Society by "unwittingly straying into the domain of a new and unfamiliar caste system", and how eventually his scientific deputation in 1914 gave him the opportunity of establishing his theories and results "before the leading scientific societies of the world", and

how "the importance of the Indian contribution to the advancement of the world's science" was recognized.

Bose emphasized that there were at that moment "two complementary and not antagonistic ideals before the country": On the one hand, India must become an industrially and commercially developed nation, so that her existence was not imperilled. On the other hand, she must not compete with the West in a mad rush for exploiting science "not so often for saving as for destruction". The complementary ideal that can "save man from that mad rush" is the ideal of "self-renunciation in response to the highest call of humanity". Bose called on his disciples to "devote their whole life with strengthened character and determined purpose" to the pursuit of knowledge "for its own sake", so that they could "see truth face to face".

Bose drew the attention of the audience to the fact that the work already carried out in his laboratory on the response of the living and non-living had "opened out very extended regions of inquiry in Physics, in Physiology, in Medicine, in Agriculture and even in Psychology. ...The fuller and fuller investigation of the many and ever-opening problems of the nascent science which includes both Life and Non-Life are among the main purposes of the Institute I am opening today. .....But high success is not to be obtained without corresponding experimental exactitude. .....Hence the long battery of super-sensitive instruments and apparatus, designed here, which stand before you in their cases in our entrance hall. .....I see at no distant future an advance of skill and of invention among our workers; if this skill be assured, practical applications will not fail to follow in many fields of human activity." Bose specifically referred to the role his crescograph was expected to play in practical agriculture. Thus he envisaged practical applications of the scientific results arrived at through the pursuit of knowledge for its own sake.

The principal object of the Institute, Bose stated, was the advancement as well as diffusion of knowledge. "The lectures given here .....will announce, to an audience of some fifteen hundred people, the new discoveries made here, which will be demonstrated for the first time before the public. .....Through the regular publication of the Transactions of the Institute, these Indian contributions will reach the whole world. The discoveries made will thus become public property. No patents will ever be taken. .....It is my further wish that .....the facilities of this Institute should be available to workers from all countries. 'In this I am attempting to carry out the traditions of my country, which so far back as twenty five centuries ago, welcomed all scholars from different parts of the world, within the precincts of its ancient seats of learning, at Nalanda and at Taxila." Here Bose stressed unequivocally the international character of science.

Bose pointed to an alarming and "excessive specialisation of modern science in the West" that "led to the danger losing sight of the fundamental fact that there can be but one truth, one science which includes all the branches of knowledge" He referred to how through his researches in Hertzian waves he devised the artificial retina and how the study of its "fatigue led him eventually into the study of plant response and its identity with animal response. Emphasizing the idea of unity of science, Bose said : "On looking over a hundred and fifty different lines of investigations carried on during the last twenty-three years, I now discover in them a natural sequence.

Bose touched upon the experiments he had carried out retrievable "memory impressions" even in inorganic matter remarked : "Thus the lines of physics, of physiology and of psychology converge and meet. And here will assemble those who would seek oneness amidst the manifold. Here it is that the genius of India should find its true blossoming."

In concluding the address, Bose explained why he chose the representations of the *Thunderbolt (Vajra)* and a half of an *Amlaki* fruit as symbols of self-renunciation that adorn the cornices of the Institute. Asoka not only renounced all his earthly possessions but gave away even his last possession which was nothing but a portion of an *Amlaki* fruit. As to the thunderbolt, the story of Sage Dadhichi is well known. 'Bose said : "Asoka's emblem of the Amlaki will be seen on the cornices of the Institute, and towering above all is the symbol of the thunderbolt. It was the Rishi Dadhichi, the pure and blameless, who offered his life that the divine weapon, the thunderbolt, might be fashioned out of his bones to smite evil and exalt righteousness. It is but half of the *Amlaki* that we can offer now. But the past shall be reborn in a yet nobler future. We stand here today and resume work tomorrow so that by the efforts of our lives and our unshaken faith in the future we may all help to build the greater India yet to be."

Let us mention in passing that in the same year, 1917, Bose was conferred the Knighthood. Interestingly, his close friend Tagore, who himself relinquished this title two years later in the wake of the Jalianwallah Bagh carnage, referred to Bose as 'Sir+ Jagadis' in the J. C. Bose Memorial Address delivered at the Bose Institute in November '1938, i.e. a year after Bose's death. By that time the days of the alien rule in India seemed numbered.

Right after the foundation of the Institute Bose began to publish his plant-physiological investigations in the *Transactions of the Bose Research institute*; the first set of investigations. bore the title "Life Movements in Plants" Volume I (1918). In January 1918 he delivered a lecture on autographic revelations of plant life and explained the workings of his crescograph before an audience, which included Lord Ronaldshay, Governor of Bengal.

Bose demolished the "mystery" of the "praying" palm tree of Faridpore. This was about a date-palm tree which had been affected by a storm and thereafter remained leaning at an angle of about sixty degree to the ground. "While the temple bells rang," says Bose, "calling the people to prayer in the evening, this tree bowed down its head *in adoration*. By the morning its head was again erect, and this process was repeated every day of the year." (italics mine) This was how the common people interpreted the diurnal behaviour of the tree. But *"natural science"*, says Bose, "does not believe in the occult, for *to it nothing is extra-physical but only mysterious owing to some hitherto unascertained cause.*" (italics mine) Bose's automatic recordings of temperature-variations and inclination-variations of the "praying" palm showed that the latter closely corresponded to the former. The upper and lower surfaces of the sprained portion of the tree responded non-uniformly to temperature-variations, and this caused the inclination-variations. "The facts show that not only the 'Praying Palm' but every tree and its different organs perceive changes in the environments and execute movements in response to them." According to Bose, the movements of the palm tree were conspicuous, because such movements were "most intense when the tree is nearly horizontal, and less so when more erect". This is an instance of how Bose through his scientific discourses crusaded against all kinds of obscurantism and occultism. It may be mentioned incidentally that in the same year Bose lectured on "The Unity of Life" and explained the principle of his Resonant Recorder in Bombay under the auspices of the Bombay University. In the course of the next year Bose delivered more lectures on plant response and brought out the Volume II of the "Life Movements in Plants". (Transactions of the Bose Research Institute, 1919).

Through these lectures and investigations Bose emphasized the basic idea of "the unity of the physiological mechanism in plants and animals". He therefore believed that "further

investigation of the simpler life of plants may be expected to lead to the solution of many intricate problems in animal life." According to him, if an animal limb is severed, the entire limb is affected by the shock. The part of the limb, inflicted upon by a knife, dies, and death travels down the limb and causes a number of interior changes. It is impossible to retard this effect in the case of the animal. In the case of the plant it is possible. The severed limb of a plant can be kept alive by artifrcial means, and that limb as well as the rest of the plant is made to remain in a normal state. Therefore, according to Bose, the results obtained from experiments on plants (if not perfectly accurate) are certainly more reliable than those obtained from experiments on animals. Thus Bose put forward the idea that for promoting the study of human and animal physiology, experimentation on plant sections may sometimes prove a better substitute than vivisection.

XI

At Home and Abroad

THE DECADE 1919-29 saw six more scientific deputations, on which Bose was sent to Europe.

During his fifth scientific mission (November 1919-May 1920) he was warmly received in England by scientists and statesmen. "It was as though", remarks Patrick Geddes, "the entire British world had been prepared, by every sort of experience, to receive and acclaim the discoveries which, in previous years, had seemed to be problematical and remote." It is noteworthy that it was in 1920 that Geddes published the remarkable biography *The Life and Work of Sir Jagadis C. Bose.* This visit of Bose was described by *The Times* (24 November 1923) briefly thus :

> "It was on the occasion of his .....visit in 1919-20 that Sir Jagadis was called to the Fellowship of the Royal Society. In Paris leading scientific men organised receptions in his honour, and in Vienna and Berlin also his work aroused enthusiastic reception.* The eminent German physiologist Haberlandt observed that it was no more accident that it should have fallen to an Indian investigator to perfect in such high measure the methods of investigation on the phenomenon of life. 'The same old Indian spirit,' he said, 'which has carried to its' utmost limits metaphysical speculation and introspection, wholly withdrawn from the world of sense, has now in its modern representative brought forth an extraordinarily developed faculty for observation and an ecstasy in scientific experimentation'

*Bose also lectured at the Physical Society of Stockholm.

Let us recall that many years back the leading authorities on plant physiology, Haberlandt and Pfeffer had challenged Bose's claim that transmission of excitation in the plant was analogous to the nervous impulse in the animal. But in 1915 Pfeffer warmly received Bose in Leipzig. And this time Haberlandt accorded Bose a warm welcome in Berlin.

In England, E. S. Montagu, Secretary of State for India, invited a representative gathering of British intellectuals at the India Office for hearing a lecture of Bose. This lecture, at which Bose demonstrated his Magnetic Crescograph, greatly impressed the audience, and prompted *The Times* to comment "Whilst we in Europe were still steeped in the rude empiricism of barbaric life, the subtle Eastern had swept the whole universe into a synthesis and had seen the one in all its changing manifestations. .....He is pursuing science not only for itself but for its application to the benefit of mankind."

Bose was invited to lecture before the universities of Oxford, Cambridge and London, the Aberdeen University awarded him the honorary degree L.L.D., and he was about to be elected a Fellow of the Royal Society. But at the same time he had to meet a challenge. His old critic and opponent Dr. Waller expressed, in a letter to *The Times*, his doubt as to the reliability of the growth-records registered by the Magnetic Crescograph. Waller challenged Bose to demonstrate, in a laboratory other than his own, that the device "gives correct record of what is undoubtedly the physiological response of the plant". The well-known scientific journal *Nature* (6 May 1920) described what followed that challenge :

> "Sir Jagadis Bose's crescograph is so remarkably sensitive that doubt was expressed as to the reality of its indications as regards plant growth : and the suggestion was made that the effects shown by it were due to physical changes. A demonstration in University College, London, on April 23,

has however led Lord Rayleigh and Professors Bayliss, V. H. Blackman, A. J. Clark, W. C. Clinton and F. G. Donnan to state in The Times of May 4 : We are satisfied that the growth of plant tissues is correctly recorded by this instrument, and at a magnification of from one million to ten million times.' Sir W. H. Bragg and Professor F. W. Oliver, who have seen similar demonstrations elsewhere, give like testimony that the crescograph shows actual response of living plant tissues to stimulus."

With great equanimity and dignity Bose stated in a letter to The Times : "If the result of my work, by upsetting any particular theory, has roused the hostility here and there of an individual, I can take comfort in the warm welcome which has been extended to me by the great body of scientific men of this country."

On 13 May 1920 Bose was formally elected a Fellow of the Royal Society - the first Indian to attain this distinction in science. Three years earlier Srinivasan Ramanujam had been elected F.R.S. for his outstanding contribution to mathematics. Bose appreciated the deliberation which the Royal Society had shown in recognising his discoveries. "This was as it should be, because unless all discoveries were critically examined, science and superstition would be inextricably mixed together".

Back in India, Bose not only brought out Volumes III .and IV of "Life Movements in Plants" (Transactions), but also a collection of popular Bengali essays, Avyakta, meant for disseminating science and scientific spirit among the common people of Bengal. Bose as a popularizer of science is discussed in the following chapter.

During 1923-24 Bose visited Europe for the sixth time. This time the audience of his lecture at the India Office, London included Ramsay Macdonald, the Prime Minister, Lord Hardinge, the former Viceroy, and George Bernard Shaw. The topic was the

"Phenomenon of the Growth of Plants". The Times (24 November 1923) reported Bose's visit :

> "The most eminent man of science India has given to the world, Sir Jagadis Bose, is revisiting this country afters an interval of nearly four years, and last week .....gave a demonstration of some aspects of the progress made in the interval at his Research Institute, Calcutta, investigating the response of plants to environment."

Bose lectured also at the University of London, the Royal Society of Medicine and the Imperial College of Science, London, the University of Prague, the Danish Botanical Society, Copenhagen, and at the Natural History Museum and the University of Paris.

1923 saw the publication of the Physiology of the Ascent of Sap (Transactions, Vol. V). This book was translated into German in 1925. Bose's investigations tended to "prove the existence of active pulsating cells throughout the length of the plant, in and from the absorbing root to the transpiring leaf. It is the pumping action of these cells that gives rise to the *physiological conduction of sap*, even in the absence of root-pressure and transpiration." (italics mine) According to the .....physical theories of Dixon, Joly and Askenasy, the ascent of sap is caused by the combined physical action of transpiration from the leaves and of root-pressure; the channel of conduction of water is considered to be through the xylem. According to Bose, on the other hand, neither transpiration nor root-pressure is essential to the process; it is the independent physiological activity of living cells that propels the sap; the dead xylem-vessels do not conduct the sap. However, Bose's above theory of the circulation of sap and his postulate of similarity of this phenomenon to the phenomena of the blood-circulation through blood-vessels and food circulation through the alimentary canal of animals have not found independent verification. In fact, no theory is capable of explaining all the

recorded observations on the movement of sap. Bose is, however, essentially right in his view that the movement of sap is more physiological than a physical process.

His book on the *Physiology of Photosynthesis* came out the next year (1924), in which he discussed his views on the plant-mechanism of storing up excess energy in a latent form. This book was translated into French in 1925. His determination of the photo-synthetic efficiency of aquatic plants has been already referred to in Chapter IX.

The same year he was nominated a member of the League of Nations Committee on Intellectual Cooperation and was invited to attend its meeting in 1926. He attended all the annual sessions of that Committee from 1926 to 1929 at Geneva. On the Committee, Bose had as his colleagues such great intellectuals as Hendrik Antoon Lorentz, a leading Dutch physicist (Nobel Laureate 1902), George Gilbert Murray, an outstanding British scholar and publicist, and Albert Einstein.

In the twenties and thirties Bose delivered convocation addresses at the Punjab University (1924), Benares Hindu University (1925), Mysore University (1927), Allahabad University, and Nagpur University (1934). He presided over the 14th session of the Indian Science Congress (1927) at Lahore. The Punjab Government presented to him the elegant wooden gateway which adorns the entrance to his Institute. He received honorary D.Sc. degree from the Benares Hindu University (1933) and from the Dacca University (1935). He was accorded in 1931 a civic reception by the Corporation of Calcutta headed by Subhas Chandra Bose, the then Mayor. On such occasions Jagadis Chandra, in his addresses, not only touched upon his pioneering researches, but also exhorted the youth of our country to dedicate themselves to the pursuit of science and "to bring the science of the East and of the West into closer affinity for the benefit of humanity". All this makes it evident that Bose never

lived a cloistered life in the ivory tower of 'pure' knowledge. He firmly believed that scientists were primarily social beings with great responsibilities to mankind. And true to his conviction he associated himself with all that would contribute; to the public will.

During his six-month stay abroad in 1926 (ending in October) Bose expressed to some British scientists his worries about the finance needed for keeping up and expanding his Institute. They shared his anxieties, and twenty-seven leading scientists, statesmen and publicists jointly submitted a memorandum (August 1926) to the Governor-General of India :

> ".....We beg to draw the attention of your, Excellency to the recognised position in the, scientific world which has been attained by the Bose Institute for the advancement of science..... We venture .....to express the opinion that the Government of India will be well-advised to continue and extend its assistance for the expansion of the Institute, so that its recognised usefulness may go on increasing and thus help to revive the ancient traditions of India as a home of learning."

It was signed, among others, by Charles Sherrington (President of the Royal Society 1920-25), Lord Rayleigh, Oliver Lodge, S. H. Vines, Julian Huxley, Michael Sadler, R. A. Gegory (Editor, Nature), Lord Burnham (of Daily Telegraph), C. P. Scott (Editor, Manchester Guardian), and Lord Grey of Fallodon (Secretary of State for Foreign Affairs). The Government of India sanctioned in 1929 an additional grant for extending the Institute laboratories.

Bose met in Paris the famous French philosopher, Henri Bergson, who received the 1927 Nobel Prize for literature. Bergson remarked : "The dumb plants had, by Bose's marvellous inventions, been rendered the most eloquent witness of their hitherto unexpressed life-story. Nature has at last been forced to

yield her most jealously guarded secrets". Bose was invited by the King of the Belgians to deliver a lecture at Brussels. The King had already visited the Bose Institute during his tour in India. The plant-specimens needed for the lecture-demonstration were grown in the King's palace garden. He himself chaired the lecture meeting and conferred on Bose the Decoration of "Commandeur Ordre de Leopold".

The period 1926-29 saw the publication of the books, *The Nervous Mechanism of Plants; Collected Physical Papers; Plant Autographs and their Revelations; The Motor Mechanism of Plants; and Growth and Tropic Movements of Plants.*

The book The Nervous Mechanism of Plants was dedicated to Rabindranath Tagore, who received it at Santiniketan just on his return (December 1926) from Europe. That was the time when the Hindu-Muslim communal problem descended to a bottomless abyss of hatred and violence. This greatly depressed Tagore. But he found solace in this book. Tagore writes in a letter (28 December 1926) to Bose : "Back in homeland after a long stay abroad I felt that all my joys were fading away, but the moment your book, dedicated to me, reached my hands, I realized that here lies our truth, this is light, this is life — this is the eternal identity of India. The message of your friendship conveyed through this book delighted me greatly — the shadow of depression that had gripped my mind almost disappeared." Bose dedicated his book on Plant Autographs to his wife.

Bose had to depend not only on government grants but also on the munificence of affluent donors for financing the Institute. For example, Maharajah Manindra Chandra Nandy of Cossimbazar financed the printing of the book on the Ascent of Sap. Similarly, in acknowledgement of such an aid by the Maharajah of Patiala, Bose dedicated his book on the Growth and Tropic Movements of Plants (May 1929) to him "for his enlightened and generous interest in the Bose Research Institute."

Bose addressed the International Conference on Educations Locarno (August 1927) after attending the League of Nations meeting at Geneva. His ninth scientific mission to the Continent and Egypt in 1928 was, so to say, a triumphal visit. The University of Vienna gave him a great ovation, and the Rector of the University wrote a letter to the Viceroy of India expressing their appreciation of Bose's remarkable contributions to theoretical and practical science. In June 1928 Bose delivered two lectures at the Plant-physiological Institute of the Vienna University. The topics were : "The Plant as a Sentient Being" and "The Action of Drugs and Alkaloids on the Pulse-beat of Animals and Plants" ("Die Pflanze als empfindendes Wesen" and "Die Einwirkung von Drogen und Alkaloiden auf den Pulsschlag des Tieres und der Pflanzen"). Prof. Hans Molisch, a leading plant-physiologist of modern ' times (see Chapter IX), paid tribute to Bose's scientific discoveries, and said that their application to agriculture and medicine would benefit mankind. Bose was elected an honorary member of the Academy of Science, Vienna. Let us recall (see Chapter IX) that it was in the same year that the German version of Bose's book on Plant Autographs and their Revelations ("Die Pflanzen-Schrift und iher Offenbarungen") came out with a foreword by Molisch. Professor Molisch came to the Bose Institute in the same year as a visiting professor, and also attended Bose's 70th birthday celebration at Bose Institute.

The same year Bose visited Egypt. The Minister of Agriculture of Egypt had conveyed the eagerness of the Egyptian Government to receive Bose as a state guest. He was received at Cairo by the King, who had made special arrangements for showing the guest all the chief educational institutions there. The Government requested Bose to select some Egyptian researchers as his disciplies. His lecture-demonstration at the Royal Geographical Society, Cairo had a great impact on the audience. A leading Egyptian periodical commented : "The Orientals rejoice at the name of Sir Jagadis Bose by whose efforts new branches of

knowledge have been opened upon science. Let us draw a lesson from the genius of Sir Jagadis, and strive after his example for the welfare of our country and the welfare of the whole world."

Bose returned to India in September 1928. The Youth League of Bombay accorded him a warm welcome on landing. On his part Bose urged the youth of India to shed all kinds of parochialism and to rise to the occasion, when India greatly needed their unstinted efforts to make her stronger and happier. He advised them not to seek "a loop-hole of escape" by saying `I will try', when they are entrusted with some task; "it is the habit of weakness to throw blame on others, on the University, on Government, on unfavourable circumstances in general. It is not for a man to complain of circumstances in general, accept them, confront them and dominate them. Learn once for all to choose what you are going to do, and say 'I will'.

This warm ovation was, however, followed by somewhat unpleasant incident. Prof. R. H. Dastur, Chief Professor of Botany at the Royal Institute of Science, Bombay contested Bose's view that the phloem in the plant played the role, which the nervous tissue played in the animal. According to Dastur, the phloem chiefly conducted food materials and not nervous impulses. One would expect a kindly and patient reply from no less a person than Bose, who was usually ready to help young intellectuals in their quest for truth. However, no genius is free from blemishes. Instead of entering into a serious discussion with Dastur, Bose brushed aside his contention with a curt rebuff : "The greatest scientists in the world have accepted my theory, and I cannot *condescend* to enter into a controversy with a novice in science."(italics mine) * Let us recall (see Chapter IX)

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*Cf. Rabindranath Tagore by Hiranmoy Banerjee (in 'Builders of Modern India' series), p. 118. On the occasion of the public reception give to Tagore at Santiniketan after the Nobel award, Tagore "used some hard words on the admirers who had assembled there to pay him homage".

incidentally that even Prof. Molisch, who was an admirer of Bose, reserved his own opinion about the latter's view on the function of the phloem in the foreword to the German version of Plant Autographs and their Revelations.

On the 30th of November 1928 Bose completed seventy, and December 1 saw the festive celebration of Bose's birthday at his Institute. As already mentioned (Chapter VII) Tagore took the initiative in celebrating* the occasion in a befitting manner. Tagore was assisted among others by Ramananda Chatterjee, and Dr. Bidhan Chandra Ray. On the eve of this celebration (on 29 November 1928) Bose delivered a lecture, "Plant as an Anchored Animal". Although Bose never sentimentally attributed human qualities to plants, he did not look upon them as insentient automatons either. Bose's discerning understanding of the plant-sentience was shared by his poet-friend Tagore on a lyrical plane. This found expression in a splendid dedicatory poem composed by the latter for this birthday celebration. Tagore concludes this poem reminiscing that he; had stood by his friend when the latter had to wade alone through agonizing sufferings; and now, in the hour of his spectacular triumph, the poet would join the multitude in singing his praises. Significantly, Tagore included this tender verse in his book of lyrics, Vanavann the MESSAGE of the FOREST — published three years later. The scientist's investigation of the PLANT RESPONSE conveyed to the poet the MESSAGE of the FOREST!

On the occasion of this birthday celebration many messages of goodwill came from abroad, among which those from Romain Rolland, George Bernard Shaw, Sir Richard Gregory (Editor of *Nature*), Sir John Farmer of the imperial College of Science, London, the Editor of *the Spectator*, London, and the Education Minister of China were noteworthy. As already mentioned, Prof.

*See Calcutta Municipal Gazette (J. C. Bose Number) Vol. IX, No. 3, Saturday, December 1, 1928.

Molisch attended the celebration and paid an eloquent tribute to Bose. It shoud be mentioned in this connexion that earlier Bose had met Rolland in Paris, where he put up at Rolland's house. Rolland at that time had presented a copy of his *Jean Christophe* to Bose. And Bose was presented by Shaw with a special edition of his collected works that bore the inscription : "From the least to the greatest biologist".

At the end of the birthday meeting Bose expressed his thanks to all well-wishers and said in the course of his reply :

> "The struggle in which I have been engaged for the last forty years has been to win for India a recognised place among the federation of nations by her contributions for extending the boundaries of knowledge. The world is today divided into warring hosts threatening destruction of civilisation. There is only one other alternative to save the world from ruin, and that is by intellectual co-operation for the common benefit of mankind. And this has been the message of the East, the latest expression of which I have just received from China* for lifting science into the realm of spiritual reality and declaring that like the unity of all aspirations by which alone continuity of human civilisation can be assured. ...If one reads the history of this country [India] aright, he will realise that India has a great assimilative power by which many races and people come to regard this country as their home, and in the service of which they gain their highest reward. ...There is an Unseen Power which ...guides the onward march of the children of

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*This refers to the telegraphic greetings message from the Education Minister of China :

"Many happy returns to life devoted to discovering ultimate truth and mystery of life. World looks to you to lift science into realm of spiritual reality. All Asia shares in` your glory.

this great land inspiring them with a burning faith in the renewal of India's ancient greatness."

1929 saw his last visit to Europe. Besides participating in the League of Nations meeting at Geneva, Bose spoke on "The Revelations of the Unvoiced Life of Plants" before an audience of scientists and statesmen at the India Office, London. This time the Editor of the *Spectator*, the well-known London periodical, gave a lunch in honour of Bose. Among the guests there were some outstanding litterateurs such as John Galsworthy, William Butler Yeats and Alfred Noyes, who eagerly met Bose and considered him a cultural envoy from India. The synthetic philosophical outlook that underlay Bose's scientific work had a natural appeal for the sensitive men of literature.

Bose devoted the last eight yeas of his life to the work of editing the *Transactions of the Bose Research Institute*, and he also supervised the plant-physiological researches pursued in his Institute. He had to withdraw gradually from active participation in those investigations because of his long-standing ailments — diabetes and high blood pressure. He needed rest, and therefore chose Giridih (Bihar) — a health resort — for a sojourn in November 1937. He corrected the final proofs of the *Transactions* and passed these for press on 20 November. Two days later he instructed the *Superintendent* of the Institute to dispose of his residuary properties, amounting to a few lakhs, to endow research and social work. Bose and his wife were to return to Calcutta, before 30 November — his eightieth birthday, which Mrs. Bose was planning to celebrate at the Bose Institute. But on 23 November his heart failed — "the heart that had sustained him for over thirty years to wage a war singlehanded to establish truth". Jagadis's close friend Tagore had been seriously ill two months before the former's death but was "wrenched back from the grip of death". The convalescing poet lost no time in writing to Abala Bose a short consolatory letter (dated 24 November 1937) :

" ... Only a few days ago I came back from the door-step of death — I have made his acquaintance, I am no more afraid of him. I know that I am about to reach my journey's end. ...You have served him [Bose] with remarkable devotion and care. What you have done for him will invest the rest of your life with sublimity and will elevate your grief to lofty height's."

XII

A Popularizer of Science

THE GREAT PHYSICIST SIR J. J. THOMSON wrote the foreword to Bose's *Collected Physical Papers* (1927). At one place of the foreword, Thomson says :

> "The papers make very agreeable reading, for the author is never dull. Another aspect of these papers is that they mark the dawn of the revival in India, of interest in researches in Physical Science; this which has been so marked a feature of the last thirty years is largely dues to the work and influence of Sir Jagadis Bose."

In renascent India, Bose played an important pioneering role not only in initiating a tradition of specialized scientific researches, but also in disseminating new scientific ideas as lucidly and unesoterically as possible among the lay readers. J. J. Thomson's remark on Bose's lucid style refers evidently to his papers written in English. However, Bose started popularizing his scientific ideas and findings through essays written in his mother tongue, Bengali, as early as 1890's, i.e. when he began his specialized investigation of Hertzian waves, publishing the results in scientific journals. Evidently the medium of communication was English. The quotations from his scientific papers, used in the present book, clearly show the facility with which he expressed himself in English. But his pen was no less facile in expressing his ideas in Bengali.

In 1921 Bose brought out a collection of Bengali essays, *Avyakta* (the 'unmanifest') written since 1894 in different magazines. Apart from the easy flow of his language, some remarkable features characterize the contents of these essays --a

philosophical and artistic view of the world around us, and fine touches of humour.

Some of these touches (translated into English) may be illustrated here.

About the use of locks of hair for polarizing electric radiation Bose wrote with a remarkable touch of humour in a popular Bengali essay; in the following quotation the mention of Paris and Berlin relates to his lectures subsequent to those delivered in England in 1897 :

"I discovered another method of polarizing electric waves. Although the invisible light enters the locks of hair of ladies in a disorderly manner, it cannot come out of the locks, because it is caught there. From the shops of hair-dressers abroad I collected various kinds of hair-locks belonging to different races. Among those, the ones belonging to French ladies were found most effective. In this respect the golden hair-locks of German ladies proved far inferior. When I demonstrated this experiment in Paris, this new phenomenon caused excite-ment among the audience of French learned people; this undoubtedly proved their superiority to the alien race! Needless to say, I refrained from showing this experiment in Berlin."

Another example may appear interesting. In describing his crescograph in an essay ('Ahata Udbhid', i.e. `injured plants'), Bose says how his nationalistic sentiments had prompted him to give Sanskritic names to his instruments on the model of English scientific terms, coined from Greek and Latin words. But he was shocked to find during his visit to the USA in 1915 that an American professor unwittingly changed beyond recognition the pronunciation of the name of his devices; Bose then says :

"I realized that one can rather make Hiranyakasipu utter hari [God], but it is impossible to make an Englishman pronounce Bengali or Sanskrit words. Such attempts result in the

transformation of hari into 'Harry'. In view of all this I have lost my enthusiasm for giving my new instrument the name 'Briddhiman' [i.e. 'growing' or 'crescent' in Sanskrit] — Briddhiman would become `Burdwan'!* I would rather call it the 'Crescograph'."

In an inimitable style, Bose explains to the lay reader the phenomenon of the polarization of Hertzian waves. He asks the reader to imagine that a group of tortoises and storks is shooed away in front of a vertical grating; only the storks can escape through it, but the flat tortoises cannot. If another vertical grating is placed before the storks after they have passed through the first grating, all of them can escape through the second. But if the second grating is turned through a right angle to make it horizontal to the ground, the storks cannot cross this hurdle. Bose then explains how a polarizer and an analyzer (see Chapters V & VI) function. He gives this simple and funny example not only to explain the phenomenon in a non-technical language, but also to create a genuine interest in science among Bengali lay readers.

Although Bose's plant-physiological researches came in the wake of his physical researches, his essays on plant life written as early as 1894-95, specifically for children, are unique examples of how the author instils into them not only a scientific understanding of plant life, but also a tender feeling for plants as sentient beings. It is noteworthy that in such a juvenile essay of 1894 Bose wrote : "Plant life is only a shadow of human life." His later plant-physiological findings were, as though, the scientific confirmation of that early statement.

In many of his Bengali essays Bose emphasized that the entire field of knowledge is one. Scientists, philosophers, artists

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*The name of the town, Bardhaman (Which means Briddhiman), has been anglicized by the British as 'Burdwan'.

and poets pursue their endless quest for some eternal and ultimate truth, though they move along diverse pathways. He aimed at developing in the minds of young readers a philosophical insight into the workings of Nature.

Bose's approach to the problem of disseminating science in India is clearly expressed in the following interview given in 1905 to the editor of a Bengali magazine, *Bhandar*. The editor was Rabindranath Tagore :

EDITOR :

"Should the standard of education and examination in our country be made stiffer?

BOSE

"...It is common knowledge that study of science in our country has not been widespread even among the educated. One proof of this is that our science has not advanced to the extent our indigenous literature has.

"In such a situation, our universities must proceed by critically analyzing the circumstances and inadequacies of our county. If we try to imitate other countries, we won't get the benefits which they enjoy; moreover, we would be deprived of the benefits that we could hope to get...

"When one intends to introduce a new trade in our country, what procedure is adopted? What has been done to popularize tea among Indians ? Arrangement has been made for selling tea on the cheap throughout the country, so that more and more people develop a taste for it and become addicted to it. Marketing a very high-quality tea at high prices has not been considered an effective way of popularizing it.

"New knowledge should be introduced in our country in the same manner. Our method of instruction must be made

simple in order to create a taste for all that is introduced for the first time. A Stricter policy for education may be considered only when education strikes root among many and our countrymen develop a taste for knowledge.

"It is pointless to feel a false shame at failing to attain, at one sweep, the standard of the foreign universities. A poor man should not be advised to give up milk, only because in the royal palace others are regaling themselves with milk delicacies. We must pay attention to whatever is needed for our nutrition; we may think of glory later on.

"Another point deserves consideration. Inventive and innovative powers are not developed merely by dealing with difficult problems and sophisticated theories of science. Acquaintance with Nature and keen power of observation constitute the chief capital of a votary of science. Persons renowned for scientific wisdom did not necessarily pass through the rigours of very difficult examinations at school.

"If we wish to see the emergence of real savants in science, we cannot expect to achieve the desired result simply by introducing a difficult standard of education and examinations. What is needed is dissemination of general scientific ideas in our country. Students must not be confined to dry, bookish knowledge; they must have opportunities for developing scientific insight into the workings of Nature through keen observation. Suitable ways must be devised to these ends."

XIII

The Fly-wheel of his Life

BOSE'S WIFE, ABALA WAS the daughter of Durgamohan Das, a well-known lawyer of Calcutta and an uncle of Deshbandhu Chittaranjan Das. She studied medicine for four years at the Madras Medical College. After her marriage she identified herself with all that her husband stood for. She was his unfailing companion in his journey to the Himalayas, to Taxila, Nalanda and other places of interest, both in India and abroad. Bose's biographer Patrick Geddes rightly described her as the "fly-wheel" of her husband's life :

> "Her's has been no simple housewife's life, but one full of active culture-interests also, not only appreciating her husband's many scientific problems and tasks, and hospitality to his students and friends, but sharing all his cares and difficulties, and so lightening them not a little. For his impassioned temperament — in younger days doubtless fiery, and still excitable enough — her strong serenity and persistently cheerful courage have been an invaluable and ever active support, like the fly-wheel steadily maintaining and regulating the throbbing energies of the steam-engine. Pilgrimages in India and visits to Europe and America have been made always together, and their one great common sorrow - the loss of their only babe in early infancy — has made them more completely at one. Alike for physical health, on the whole well maintained, yet once and again nursed back from danger, and for steadiness of intellectual output, for consolation in times of trial, difficulty and lightening of long years of poverty and self-denial — which cannot but press more closely upon a wife than on

a husband — Bose has indeed been rarely fortunate in such a helpmeet; and no friend or biographer could fail to recognise the greatness of her share in his life's productivity and success."

As to her "hospitality to his students and friends", it should be mentioned that Prafulla Chandra Ray, after his return from Edinburgh, stayed with the Boses for about a year. Prafulla Chandra was a frail young man. Moreover, at that time he was suffering from mental agony because of discriminatory treatment, the like of which Jagadis Chandra too had to protest against in connexion with his own appointment a few years earlier. With loving care and affection Abala Bose nursed Prafulla Chandra back to health. Whenever Sister Nivedita fell ill, it was again Abala Bose, whose affectionate nursing restored her to health. We may recall that it was in Bose's Darjeeling resort that Nivedita breathed her last. Bose's research students found in Mrs. Bose a loving mother.

The great fortitude with which she shared the tribulations of her husband after his appointment at the Presidency College has been already mentioned.

After Bose's retirement, Abala Bose devoted herself to the work of women's education and welfare. They chief object of he Nari Siksha Samity (the Women's Education Society) established by her was "spreading of education — general and technical — among girls and women in Bengal so as to make them good wives and mothers and devoted social workers."

XIV

Jagadis Chandra's Lifework : An Overview

A NINETEENTH-CENTURY GERMAN thinker characterized the European Renaissance as :

> "... the greatest progressive revolution that man has so far experienced, a time which called for giants and produced giants — giants in power of thought, passion, and character, in universality and learning. ...The heroes of that time had not yet come under the servitude of the division of labour, the restricting effects of which, with its production of onesidedness, we often notice in their successors. .....They almost all pursue their lives and activities in the midst of the contemporary movements in the practical struggle; they take sides and join in the fight, one by speaking and writing, another with sword, many with both. Hence the fullness and force of character that makes them complete men."

The Indian renaissance could not attain the scale and intensity of the European Renaissance owing to the cramping historical factors inherent in an alien rule. Yet some great Indians or "heroes" perceived the contemporary needs of our country by dint of their "power of thought" and "`passion".' They Were indeed men of character and "giants in universality". "Division of labour" in the sense of professional specialization is a necessity in a developed and advanced human society, but they did not come under the "servitude" of specialization. They were specialists in their respective fields of knowledge and activities, but at the same time they were free from the "one-sidedness" of

specialization. It was their "force of character" and "universality" of vision that prompted them to associate themselves with "contemporary movements", in which they "took sides and joined in the fight" for truth and justice.

Jagadis Chandra Bose was one of "the heroes of that time". His participation in contemporary movements, his passion and power of thought, and the fullness and force of his character found expression not on a restricted political plane, but through his sustained lifelong work which proved that "the Indian mind" was "as capable of excelling in science as in literature or philosophy". Bose's patriotism was cast in a special mould. He reasserted our intellectual heritage through imaginative, patient and bold efforts to graft our synthetic philosophical discernment of Nature into the rigorously analytical scientific method of the West. However, this intellectual struggle was not confined to any ivory tower of cold academicism. Bose indeed had a truly academic mind, but at every stage of his involvement in research he was very much aware of his social responsibility to his countrymen. He felt that his compatriots had the right to advanced scientific education and research facilities. His awareness of this desideratum in our national life led him to not only petition the Government to provide such facilities for our universities, but also to found a research institute where "the genius of India should find its true blossoming".

Such initiatives and endeavours in the cause of science and education show a great force of character, which once impelled Bose to refuse to accept salary cheques for three years in protest against discriminatory appointment rules in the education service. In 1913 Bose protested against such invidious distinctions in a forthright statement before the public services commission :

> "Regarding the question of limitations that exist in the employment of Indians in the higher service, I should like to give expression to an injustice which is very keenly felt.

> It is unfortunate that Indian graduates of European Universities who have distinguished themselves in a remarkable manner do not, for one reason or other, find facilities for entering the higher educational service."
>
> "As teachers and workers, it is an incontestable fact that Indian officers have distinguished themselves very highly, and anything which discriminates between Europeans and Indians in the way of pay and prospects is most undesirable. A sense of injustice is ill-calculated to bring about that harmony which is so necessary among all the members of an educational institution, professors and students alike."

What goaded Bose to identify himself with the fight for the equality of opportunities his compatriots were entitled to? The answer lies in the ideas and values Jagadis imbibed in his childhood. He himself writes :

> "I now realise the object of my being sent at the most plastic period of my life to the vernacular school, where I was to learn my own language, to think my own thoughts and to receive the heritage of our national culture through the medium of our own literature. I was thus to consider myself one with the people and never to place myself in an equivocal position of assumed superiority".

With this attitude towards his countrymen he also felt an urge to popularize science among the common people around him through the language they spoke and understood.

The inimitable characterization of the great Renaissance of Europe in the quotation at the beginning of this chapter indicates that, in general, the "successors" to the Renaissance heroes gradually came "under the servitude of the division of labour" with its concomitant "'one-sidedeness". Thus a new caste system came into existence, which required specialists and experts to be confined within the limits of their own disciplines; they were not

to intrude into other specialized branches of knowledge. Bose's synthetic Indian mind could discern signs of a basic unity in diverse inorganic and organic phenomena. And he boldly presented his ideas before the leading western physicists, chemists and physiologists. But he was shocked to discover the hold of the new caste system on many of them. We have seen how eventually his synthetic view of Nature prevailed over the one-sided views of some veteran scientists who had resented his incursions into their domain.

We should not judge Bose's borderland work on the response of inorganic and organic matter and on plant life by taking stock of how much of it has stood the test of later investigations based on advancing experimental techniques and theoretical ideas. For example, such chemical mediators as auxins and some other growth hormones had not yet been discovered during the period of Bose's active research. He belonged to the generation of electrophysiologists who attributed a decisive role to bioelectric currents in controlling all organic phenomena like growth, cell division, secretion, etc. Evidently, we cannot expect the whole body of Bose's biophysical findings to survive. Nevertheless, we cannot ignore the importance of his contribution. He was indeed one of the master minds whose synthetic approach to physics, physiology and psychology inspired a generation of scientists to take a unified view of Nature, that crystallized into the science of cybernetics. Bose's galena detector could have earned him a Nobel award, if he had clung to it like many of his patent-greedy contemporaries. But he looked upon his device not simply as a potential gem in wireless telegraphy but as one that pointed to the confluence of seemingly disparate sciences.

Bose's work on plant life deserves special consideration. At the beginning of his paper "Is the Plant a Sentient Being?" (*The Century Magazine*, Vol. 117, Feb. 1929, No. 4, p. 385-393), Bose writes :

> "According to the best traditions of ancient India, there can be no conflict between knowledge and religion, for the highest knowledge is religion. Therefore, the house of knowledge is not a mere laboratory, but a temple. It was with this idea that my Research Institute was founded, where scholars devote their whole life to pursuit of knowledge for the common benefit of humanity."

From this statement our readers are free to interpret the meaning of religion according to their inclinations. However, one thing is certain from this. His 'temple' was not meant for introspective exercises removed from Man's material and cultural needs. Bose was not steeped in any religious obscurantism. His was a rigorously scientific approach unbefogged by emotion, though free from the one-sidedness of rutted specialization. This aspect of his mind takes on a special significance in the context of the battle continually being waged against the forces of irrationality — not only many antiscientific trends of the Indian mind but also the findings of the pseudo-scientific plant-physiological researches carried out by some western scientists. To be specific, two American journalists Peter Tompkins and Christopher Bird brought out in 1973 a 'best seller' The Secret *Life of Plants*, which seriously discusses, among other things, some electrophysiological experiments on plants carried out in the late 1960's by a polygraph expert Cleve Backster. Tompkins and Bird claim :

> "Evidence now supports the vision of the poet and the philosopher that plants are living, breathing, communicating creatures, endowed with personality and the attributes of soul."

Investigations conducted by Backster and his follower Marcel Vogel are claimed to indicate that plants have "extrasensory perception", and that "plants can read your mind". Vogel even claimed in a lecture given at the Bose Institute

(1978) that he had influenced plant growth by meditation. Tompkins and Bird eulogize Bose, and assert that "the startling discoveries of several scientific minds [in the U.S.A. and U.S.S.R.] in the 1960's" have brought "the plant world sharply back to the attention of mankind" ending a neglect of about half a century. But let it be re-emphasized that Bose, in referring to the plant as a "sentient being" or "an anchored animal", never meant that its sentience was comparable with that of humans and higher animals. On the contrary, he stated categorically (Convocation address at the University of Punjab, 1924) :

> "There are some ...who without any proof, but *through mere sentimentality,* attribute to plants even *human qualities.* But *these imaginings cannot, in any way advance exact knowledge.* The similarity, if any, between plant and animal life can only be established by demonstrating the unity of physiological mechanism in all life."

It would bear repeating that in describing the 'Praying' Palm of Faridpore, which bowed down its head in the evening, Bose showed that it was not an "extraphysical" phenomenon; to "natural science nothing [is] occult or extraphysical, but only mysterious owing to some hitherto unascertained cause". Fortunately, some American botanists and physiologists have come forward to combat the pseudoscientific myth about plant sentience preached by Tompkins and Bird.

The message left by Bose's lifework is that while the poet's and the philosopher's visions of Nature complement the scientist's view of the physical world around us, the scientist can hope to approximate to the goal of his inquiry only by keeping his intellect free from all varieties of lyrical exuberance and transcendentalist inspiration. Throughout his life Bose believed that the scientist, the philosopher and the poet played complementary roles in the quest for a unified view of Nature.

The scientist however was to play a special role through his crusades against the obscurantist and the doctrinaire. It was given to the scientist to combat all dark forces that could stupefy the human intellect. The task was indeed one of saving the purity of the spirit of science.

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CONTENTS

*i.e. 1921

Appendix I

54 Parliament Street
London, S.W.
16 July 1901

My dear Robi,

I was glad to learn that some of our countrymen have been thinking of making arrangements to make Dr. Bose independent of the Government appointment which he holds, so that he may pursue his researches all his life to the credit and honour of our country. The idea is an excellent one, because the chance we have now will probably never return within a generation, if we lose it now. Dr. Bose has read startling papers and disclosed startling discoveries at the Royal Institution & the Royal Society, he has awakened the interest of the civilised and scientific world, and he is on the eve of revealing farther truths which will give our countrymen a position and name. But to pursue his work to a successful termination against all opposition is a work of years,-and during these years we must support him and keep him in his work. The Indian Govt. can't do this and won't do this. They have refused his prayer for extention, and you know as well as I, they will not be sorry to see him withdrawn from his brilliant labours into the drudgery and obscurity of Calcutta. If ever there was an occasion for us to fight for our fame and honour,—this is the occasion !

I am sure you will be able to guess, as well as I, what his expenses here are likely to be. He has to keep an assistant on about £ 200 a year, his instruments and appliances will cost about as much, and living with his wife in this country & travelling from place to place, — to Germany or America sometimes, — will cost at least £ 600 a year.

Thus a thousand pounds a year,-(or 15,000 Rupees) is what is necessary for him;—I believe Sir M. Bhownagree gets about three times as much for his political work ! Will our country fail to give our only scientist this support When so much is at stake, when a chance now lost may never come back to us ?

From past bitter experience, I would not depend on annual collections and contributions. As a friend, I would not advise Dr. Bose to give up his appointment, miserable as it is, depending on annual remittances. We must make him independent once for all, so that there may be no doubt as to his future, so that he may devote his whole time and energies to his work without any uncertainty in his prospects. I do not know how much money an Insurance Office would require in order to grant Dr. Bose an annuity of Rs. 15,000 a year for the rest of his life. I imagine they would want two lakhs or so;—and unless

we can find this sum and pay it into an Insurance Office to assure an annuity to Dr. Bose during the rest of his life I see no other way of making him independent of that drudgery, humiliation and eternal worry which are certain to ruin his chances and our country's prospects for ever.

The suggestions I have made in this letter are all my own. I feel strongly in the matter, and have thought it out, and made my own calculations. And I feel also that if we do not help ourselves in this matter, if we have not patriotism enough to make our one scientist independent for life and devoted to the cause of science and of our country, we shall lose our chance for ever and deserve to lose it. I know, Robi, you feel as strongly as I do; you have immense influence in the country; and I appeal therefore to you to try privately to raise this money & invest it in the manner proposed for the honour & the glory of our country.

Yours Ever Sincerely
Romesh Dutt

Appendix II

9, Elysium Row
Calcutta
April 18th, 1903

Dear Mr. Tagore,

You asked me to write you an account of the actual discoveries which Prof. Bose had made, & of the difficulties under which he had laboured in making them. But I imagine that you only want the kind of account that I can give you in a letter. I imagine, too, that in writing you a letter I am making a more or less confidential communication, so that I need not fear to use names occasionally knowing that I shall not be quoted in any public way.

When I came to Calcutta I first knew Prof. & Mrs. Bose, in the end of the year 1898. I was horrified to find the way in which a great worker could be subjected to continuous annoyances & petty difficulties—with the evident earnest desire of those who were about him to end his distinction which was personally galling to them. The college-routine was made as arduous as possible for him, so that he could not have the time needed for investigation. And every little thing that happened was made an excuse for irritating correspondence & flagrant misrepresentation.

These things may seem small in your eyes, but if you have the least idea (as you must have) of how impossible it is to do work requiring great insight or great & sustained emotion, unless there is freedom & peace, you will know how wonderful it is that our friend should have continued to work on & achieve, in spite of his surroundings at that time. If one could also realise, in a country situated as India is, the sacrifices that a free people, like the Americans or English, the French or the Germans wd. be willing to make in order to obtain such a worker as Dr. Bose-of their own blood - one wd. stand amazed, as I did, at the spectacle of a great scientific man working alone as he was. I had come, of course, from Europe, where Prof. Bose's name was well known as the discoverer of the Etheric Waves that penetrate minerals. His work was belated in reaching Europe. It was announced along with the Rontgen rays, & obviously went deeper-since that form of light was deterred by bone & metal, while his penetrated these substances. Already, early in the year 1895, I believe, he bad demonstrated the existence of these invisible rays at the Town Hall, Calcutta—and it was not till two years after he had thus made the essential discovery—as some of the Italian scientific papers were the first to point out,—that Marconi began to work out & apply it on the large scale.

Of course you understand that men of the inventor & discoverer type-men like Marconi, Tesla, Mascine, & so on,—rank in the world of science far

below the investigator, the man of Sannyasin mind like Dr. Bose, who pursues knowledge for its own sake. Even Prof..... jeopardises his great reputation, & certainly minimises his historic importance by taking patents & becoming involved in commercial schemes. But. Dr. Bose not only demonstrated the existence of these particular etheric waves. He proved himself as great in constructive ability as in research itself, & his instrument, popularly known as the Artificial Eye, was considered a marvel of compactness & simplicity. Prince Kropotkin was talking of how Prof. Thomson the week before at the Royal 'Institn. had exhibited an apparatus some yards long, to act as a polariser of light — and Prof. Bose, the following week, to do the same thing, simply took up a book (it happened to be a Bradshaw) & showed how the rays wd. pass one way & not the other. "I said to myself', said Prince K. "that this was the simplicity of the highest genius:' But of course Prof. Bose was only able to perform this great simplification of methods because his theory was so much more sound tan those of his English & German competitors in this field.

He began to publish Papers through the Royal Society in, I think, the year 1894. From that date, working under all his difficulties as he was, he published 2 or 3 every year till he left for Paris in 1900. (One Paper in two years is considered a good record for a life that is surrounded by advantages.) And Prof. Bose's work was in each case completely original & in a special sense accurate & exhaustive. He was like a man haunted by the fear that if he failed at any point his people wd. be held to have no right to education. "Everyone knows that we have brilliant imagination" he told me, when he was fighting against death in London in 1900, & still struggling to make a record of his latest discoveries, "but I have to prove that we have accuracy & dogged persistence besides." He did prove it. Lord Rayleigh & Sir Wm. Crookes both told him that while the perfection of his methods was unquestioned, no one had yet been able, in 1901, to repeat his experiments of 1895-6. His manipulation was beyond rivalry.

The work of '94 to 1900 had consisted of some dozen or more separate investigations on invisible light-polarisation. The existence of a dark cross— &c. &c. — these were valuable pieces of work, full of suggestions to some of the advanced workers in Europe, who were not slow to take hints from his instruments & theories. It was apparently in the year 1900, however, that all these separated tasks began to combine in a series of great generalisations which have not yet been given to the world in their completeness, and which are to prove of wider & wider philosophic interest as time goes on.

I allude to the great Theory of Stress & Strain — which, if only he can command time & strength to work it out in publication, will be held as epoch — making as Newton's Law of Gravitation — a tribute worthy of India's contributing to world-knowledge.

It is the minor applications of this generalisation that have hitherto attracted so much attention- one of the first discoveries to which it led was that of the Binocular Alternation of Vision.

Another was of a more practical (i.e. commercial) nature —leading to the improvement of the coherer in Wireless Signalling, & Lodge's collaborator, Dr. Muirhead, freely confessed that in the development of the system lately adopted for India, they had owed most important suggestions to Dr. Bose's Papers & conversation. The largest applications of the theory are however purely scientific. It gives an immediate clue to whole classes of apparent anomalies in photography, in chemistry, & in Molecular Physics generally. Amongst other things it led to the immediate discovery & formulation of the phenomenon known as Vegetable Response. In realms like these it has disproved the contentions of many would-be theorists of a smaller scale, & there is therefore a strong opposition to Prof. Bose's work amongst those physiologists who have tried to prove the unique character of life. This opposition is of course perfectly normal. It is usually in fighting against it, that a scientific man proves his greatness, & conquers those who disagree with him. But in this case, there is a strong race-feeling of jealousy to combine with the natural & necessary scientific opposition. & I have no doubt that it was through the efforts of these men at the India Office that the opportunity was taken to refuse Dr. Bose any extension of deputation, at the moment when his opinions began to be known, & before his book had yet come out.

It was the very man of whom I have this suspicion who in November, believing Prof. Bose to be in India, (to have been forced back to India indeed) stole some of his results & published them as his own. Fortunately Prof. Bose's position in the world of Science was too well assured for him to touch it, & though he has been able to organise a small party, we may regard it as easily discredited if the work can only be continued in an adequate way.

The book on Response in Living & Non-Living is now triumphant. I want a far greater work, such as only this Indian man of science is capable of writing, on Molecular Physics,—a book in which that same great Indian mind that surveyed all human knowledge in the era of the Upanishads & pronounced it one, shall again survey the vast accumulations of physical phenomena which the 19th Century has observed & collected, & demonstrated to the empirical, machine—worshipping, gold-seeking mind of the West that these also are One—appearing as Many.

But I recognise that under present conditions one cannot even ask for the beginning of such a work. The petty daily persecution where perfect sympathy & every facility are absolutely necessary : the distracting routine of a paid servant who is never allowed to feel independent of daily bread, the constant

difficulties threw in the way by minor officials who have power enough to impede, but not enough to be raised above jealousy, — are these things not enough? And then we ask him to undertake great work — but what are we willing to do for him ? Can we supply him with companions in learning who will stimulate & encourage the arduous work ? Does it trouble us that he is the one man in India doing work of the first rank, & that to this day he is paid less than any Englishman, even the commonest, wd. receive in his place ?

Dr. Garnett of London told me of the splendour of the great College of Sciences at Vienna, and how, when he exclaimed as to its cost, the government representative replied proudly that if one scientific man shd. be produced in a century there, it wd. be more than worth their while. Which of us feels like this ?

Ah India ! India ! Can you not give enough freedom to one of the greatest of your sons to enable him,—not to sit at ease, but — to go out & fight your battles where the fire is hottest & the labour most intense, and the contest raging thickest ? And if you cannot do this—if you cannot even bless your own child & send him out equipped, then, is it worthwhile that the doom should be averted, & the hand of ruin stayed, from this unhappy & so-beloved land ?

This is all very inadequate, dear Mr. Tagore. But I have used many sheets of note-paper I see—& I must draw my letter to a close.

Ever yours faithfully

Nivedita
of Ramakrishna-V.

Appendix III

To
Jagadis Cbandra Bose
From
Rabindranath Tagore
1901

YOUNG image of what old Rishi of Ind
Art thou, O Arya savant, Jagadis ?
What unseen hermitage hast thou raised up
From 'neath the dry dust of this city of stone ?
Amidst the crowd's mad turmoil, whence hast thou
That peace in which thou in an instant stoodst
Alone at the deep centre of all things —
Where dwells the one alone in sun, moon, flowers,
In leaves, and beasts and birds, and dust and stones,
— Where still one sleepless Life on its own lap
Rocks all things with a wordless melody,
All things that move or that seem motionless !
While we were drunk with the remote and vain
Dead glories of our past, — in alien dress
Walking and talking in an alien tongue,
In the caricature of other men —
Their style, their bearing, — while we shouted, yell'd
Frog-like with swollen throat in our dark well,
O, in what vast remoteness wert thou then ?
Where didst thou spread thy hush'd and lonely mat —
Thy mat of meditation ? Thou, thy mind
Curdling into calm gravity, didst plunge
In thy great quest after the viewless ray,
Beyond the utmost borders of this world
Of visible form, there where the Rishis old
Oped, and passed in beyond the lion-gates
Of the Manifold and stood before the one,

Silent in awe and wonder, with joined hands !
O Hermit, call thou in the authentic words
Of that old hymn called Sama : "Rise ! Awake !"
Call to the man who boasts his Sastric lore
From vain pedantic wranglings profitless,
Call to that foolish braggart to come forth
Out on the face of Nature, this broad earth.
Send forth this call unto thy scholar band;
Together round thy sacrifice of fire
Let them all gather. So may our India,
Our ancient land, unto herself return
O once again return to steadfast work.
To duty and devotion, to her trance
Of earnest meditation; let her sit
Once more unruffled, greedless, strifeless, pure
O once again upon her lofty seat
And platform, teacher of all other lands.

– Translated from Bengali by
Prof. Manmohan Ghose

Appendix IV

Dedicated to the great scientist Jagadis Chandra Bose

1906

Look at my mimosa, by friend.
See what the heavens have brought her
and the wind wafted —
what strange message her heart conceals
in the folds of her leaves.
You shall have to seek out and know,
and break her eager silence.

My friend, evening is on and
a wind laden with dreams bends to kiss her.
The branches droop into sleep with leaves.
Her blue-eyed flowers gaze at the stars,
rapt in dreams we know not.
Oh, this is my mimosa.

My friend, bring your touch of lightning
that quickens with joy.
Look into her heart with kindly eyes; for
she stoops with the load of the radiant day's
memory of song and fragrance —my mimosa.

You know my friend, that small is not petty,
that even a grain of truth mirrors the world.
In the shy, closed eyes of my mimosa,
I know that you shall read
messages of life and death, of sun and shadow and storm.

My mimosa for you, my friend.

— Rabindranath Tagore

[Dedicatory poem for the book of verses Kheya

the 'ferry-crossing'.]

Appendix V

"The experimenter's is a curious and special talent. Armed with a tea-canister and some wire, with silk, a little sealing wax, and two or three jam-pots. Faraday marched forth against the mysterious powers of electricity. He returned in triumph with their captured secrets. It was just a question of suitable juxtaposing of the wax, the glass-jar, the wires. The mysterious powers couldn't help surrendering. So simple — if you happen to be Faraday.

"And if you happen to be Bose, it would be so simple, with a little clock-work, some needles and filaments, to device machines that would make visible the growth of plants, the pulse of their vegetable hearts, the twitching of their tissues, the process of their digestion. It would be so simple — though it cost Bose long years of labour to perfect his instruments."

— Aldous Huxley

INDEX

ERRATA

Page No.	Published as	To be read as
17	(Adrsya Alok) {5th line from bottom}	(Adrs´ya Ālok)
27	(Adrsya Alok) {10th line of 3rd para}	(Adrs´ya Ālok)
32	molecular change (2nd line)	in italics
32	analogy {14th line}	in italics
36	Setting {4th line from bottom}	Settling
40	rapidly succeeding stimuli {1st line of 2nd para from bottom}	"rapidly succeeding stimuli"
43	'This is.... Buddishm!..." {2nd para from lower}	'This is...Buddism!'....."
45	Our {1st line}	in italics
49	any {Ist para of foot note} Bose's role {2nd para of foot note}	in italics in italics
50	physiological {13th line} vital activity {14th line}	in italics in italics
51	in plant life." {the end of 4th line}	add [Italics mine]
52	the Secretairn General of the Society FranKaise de Physique {2nd and 3rd line from 3rd para}	the Secrétaire Général of the Française de Physique
55	my {Last line of foot note}	in italics
56	Mahabharata {9th line from top}	Mahabharata
57	Barigadarsam {3rd line from last para}	Bangadars´an
65	ratina {9th line from 1st para}	retina
69	more {2nd line from 2nd para}	mere
73	for growth" {Last line from 2nd para}	of growth"
77	Bishma's {16th line from 2nd para}	Bhishma's
86	but only {11th line}	not in italics
90	We {3rd line}	'We
94	Plant Autographs {Last line of 3rd para}	in italics

95	disciplies {4th line from the bottom}	disciples
96	in general {3rd line from last of 1st para}	but bravely
97	Vanavann {4th line from the {bottom of 2nd para}	Vanavani (and also in italics)
98	your glory {last line of foot note}	your glory."
99	Superintendent {11th line from the bottom}	not in italics
100	height's." {last word}	heights."
101	in English {6th line from 3rd para} Bengali {8th line from 3rd para}	Both in italics
102	(Ahata Udbhid) {2nd line from 2nd para from bottom}	('Ahata Udbhid')
103	hari 'Harry' {1st line} Briddhiman {3rd and 4th line}	both italics both italics
104	Bhandar {7th line}	Bhandar
113	"There are some.....in all life" {2nd para}	"There....life." [italics mine]
115	(editor: Ramanada Chatterjee) {3rd line of 2nd para}	(editor: Ramananda Chatterjee)
115	Transactions....Inst, Prabasi, American Scientist, Science Today [Name of The Journals]	all in italics See J.C. Bose 16th Edition- Page No.112
117	AVYAKTA (in Bengal) {last line}	AVYAKTA (in Bengali)
118	must, can't, won't {11th and 12th line}	all in italics
121	1895-6 {2nd para}	1895-6!
123	threw {1st line}	thrown
126	by friend {1st line} Kheya {2nd line from bottom}	my friend Kheya,
127	'device {2nd line of 2nd para}	devise

A pioneer of microwave physics, J.C.Bose anticipated the science of cybernetics that unifies physics, biology and psychology with respect to the problem of automatic control systems. He is idolised as the inventor of wireless telegraphy and as a triumphant oriental intellectual who convincingly vindicated the existence of a supreme conciousness that unifies all diversities.

The book attempts to dispel the ignorance of what Bose did. The communication between Bose and Tagore, quoted extensively here, is a rich source material for learning about him firsthand.

The author is remembered as a highly learned, self-taught, benevolent laureate. He has been associated with INSDOC Delhi, IIT Kharagpur, and INSA. Dr Mukherji wrote extensively on scientific discoveries, history of science, the Yukawa theory, evolution of steam power and electric power and Greco-Latin scientific terminologies. He popularized science among the common man through his writings.

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